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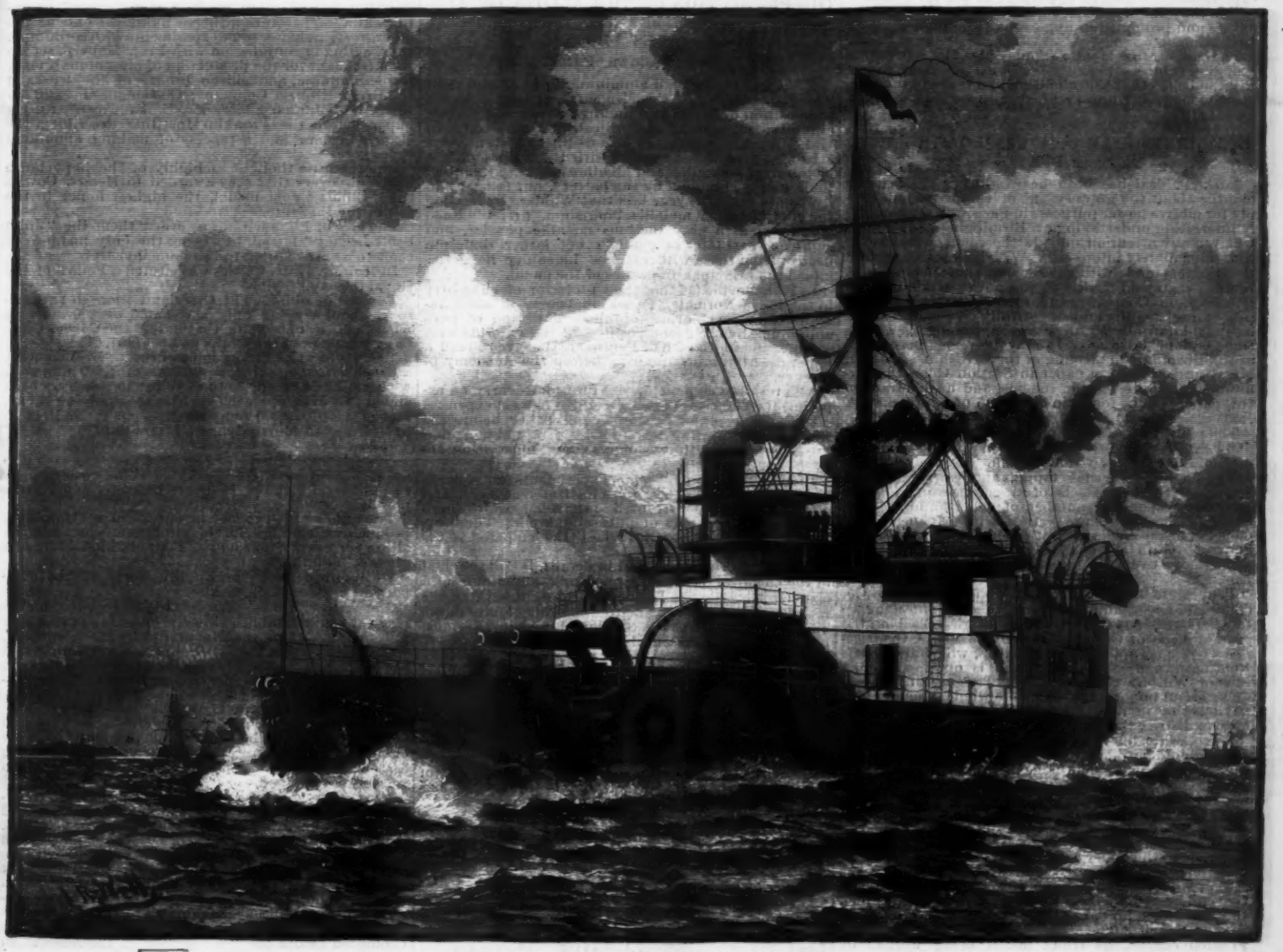
H. M. S. VICTORIA.

AN Admiralty order has been received at Sheerness directing the new first-class battle ship Victoria to be taken for a series of gunnery trials, under the superintendence of the officers of the gunnery ship Excellent. If the trials are successful, the Victoria will be immediately commissioned as the flag ship for the Mediterranean station.

The armorclad Victoria, which has been built for the British Navy by Sir William G. Armstrong, Mitchell & Co., at the Elswick ship building yard, on the River Tyne, is the most powerfully equipped British war ship afloat. Her main dimensions are: Length between perpendiculars, 340 ft.; beam, 70 ft.; mean draught with full armament and full coal stores, 26 ft. 9 in.; displacement, when completely equipped, 10,500 tons; and the power of the engines is 12,000 horse indicated. Her armament consists of two guns of 110 tons each and 16¼ in. caliber, placed in a turret forward; one 11 in. gun of 30 tons, placed aft on the upper deck; twelve 6 in. 5 ton broadside guns in a turret on the main deck abaft the 110 ton guns; twelve six-pounder rapid firing guns on the spar deck, and nine three-pounder rapid firing guns, some on the decks and some in the mastheads. There are also two 1 in. Nordenfelt two barreled guns, and four ½ in. Nordenfelt guns, placed on the spar deck or in the mastheads. The turret in which the two 110 ton guns are placed is covered with bound steel armor 17 in. thick, and the base of the turret is protected by a battery wall completely inclosing it with 18 in. thick of bound armor, which protects also the mechanism for bringing up the ammunition and driving the gun. The guns will fire a projectile of 1,800 lb. weight in any direction from straight ahead to 50 or 60 deg. abaft the beam on either side, the charge of gunpowder being no less than 900 lb. To the rear of this turret on each side of the vessel is a long, strongly protected battery of six 5 ton guns of 6 in. caliber, projecting through protected ports. These batteries extend from the turret to the station for the 10 in. gun, which is a stern gun of great range. The rapid firing guns will be on the spar deck, and, at the head of the steel mast, fore and aft and on each side, are four torpedo guns above water, and there are four under-water torpedo guns, two on each broadside. The Victoria will also be fitted with torpedo defense netting and with boats for torpedo service in action. The ship will be commanded from a conning tower of armor of from 10 in. to 12 in. thick placed above the level of the turret, which will have means of communication with the engine rooms and important parts of the ship, and of steering by hydraulic power.

The ship throughout is lighted by electricity, by which means also the guns will be fired, while the loading of the heavier guns will be carried out by means of hydraulic mechanism. The protective armor of the Victoria is very massive. For protection against heavy projectiles she has on each side a belt of armor extending three or four feet above and below the water line, and 152 ft. in length, of compound steel plating 18 in. thick. This armor incloses all the vital parts of the ship, including the propelling machinery, the magazine mechanism, the boxes of the funnels, and the structure carrying the base of the turret. A protective flat deck of 3 in. thickness of steel is carried over at the level of the top of this armor belt, throughout its length and continued to the bow and the stern of the ship. At the level of the bottom of this armor belt, at its forward end, is superimposed an 18 in. belt, which protects the base of the turret itself with armor 17 in. thick. Thus from the stem to the stern the ship is thoroughly protected either by deck plates or by massive walls of bound armor.

The propelling power, which is placed below the protective decks, consists of twin screws of 16 ft. diameter, each of which is driven by triple expansion engines manufactured by Messrs. Humphrys & Tennant, London. The cylinders of the engines are respectively 43 in., 62 in., and 96 in. diameter, and the stroke of the piston 51 in. These engines are intended to be worked at a speed of ninety-five revolutions per minute, and will collectively develop a force of 12,000 indicated horse power, giving to the vessel a speed of about 16¾ knots. The Victoria will have a coal storage of 1,200 tons, sufficient to carry the vessel at full pressure over 1,600 nautical miles, but at the more leisurely speed of say ten knots, over a distance of 7,000 miles—a long cruise. Ample magazine accommodation is got in the internal part of the ship, owing to her great beam, so that even for the 110 ton guns she will be able to carry 100 rounds of projectile and powder. The most striking feature of the whole is the extent to which manual labor has been superseded by hydraulic power, not only in the manipulation of the heavy armament, but in the engine room and in every part of the ship.—*Illustrated London News.*



H. M. S. VICTORIA, NEW FIRST-CLASS WAR SHIP.

APPARATUS FOR PROVIDING A STEADY PLATFORM FOR GUNS, SEARCH LIGHTS, TELESCOPES, ETC.

IN a paper read before the mechanical section of the British Association, Mr. Beauchamp Tower describes an apparatus large enough to carry a 3 pounder gun, which he has constructed and mounted on a 25 ton steam yacht, and which keeps perfectly steady, even when the vessel is rolling and pitching violently.

The apparatus consists of the platform, which is the part to be kept steady, and which is hung in gimbals. The steadying forces are applied by four cylinders attached to the platform, which push by means of rams at four external points. The action of these cylinders is controlled by a wheel revolving rapidly in a horizontal plane on a ball and socket bearing attached to and between the four cylinders. Water at 100 lb. pressure is pumped by a pumping engine through the gimbals, which are made hollow for the purpose, and thence through a pipe on the platform to the ball and socket bearing of the wheel, which has a passage through it for the water to pass to a cavity in the center of the wheel; from this cavity some of the water passes to

tangential jets, which cause the wheel to revolve by their reaction at about 1,500 revolutions per minute. The remainder of the water issues from an axial jet which projects upward from the wheel, and has opposite to it, and at a distance equal to about the jet's diameter, four ports grouped close together, and each connected by a passage to one of the four cylinders.

The wheel, being hung a small distance above its center of gravity, settles itself down to revolve in a truly horizontal plane, and to throw a truly vertical jet out of the axial jet nozzle. This jet striking on the four ports causes a water pressure in the four cylinders, which pressure is equal in all the cylinders if the jet is truly concentric with the four ports; but, if it is not, one of the ports receives more of the jet than the others, and the cylinder connected to it has a greater pressure, and, consequently, pushes harder than the others, and pushes the platform over till the ports and axial jet are concentric. The object and advantage of this arrangement is that while the wheel acts powerfully on the platform it suffers no reaction on itself, and no matter what disturbing forces are brought to bear on the platform, none of them can affect the wheel.

The wheel, revolving in a horizontal plane, and hung a short distance above its center of gravity, is in reality a long period conical pendulum having a period of about ninety seconds, and is analogous to Mr. Froude's wheel, which he used for recording the rolling of ships. This was a pendulum whose period was longer than that of the waves, so that it might be undisturbed by the wave forces. The author has experimented with this apparatus at sea for a considerable time, and has overcome the usual practical difficulties and brought the apparatus to a high state of perfection.

The apparatus is also applicable for controlling swinging cabins, and experience with it seems to justify the belief that the abolition of the angular movement alone would prove a great mitigation of sea sickness.

THE BIRMINGHAM COMPRESSED AIR POWER SUPPLY.

A GREAT deal has been heard during the last few months about the Popp system of compressed air supply for motive power purposes in Paris, while the equally interesting undertaking at Birmingham has hardly received any attention outside the small circle of persons immediately interested. With a view to ascertain the progress made with the Birmingham scheme, we a few days ago paid a visit to the power station of the Birmingham Company, and found that it had been proceeding steadily and successfully on the lines originally laid down by Mr. J. Sturgeon, the engineer, some three or four years ago. It may be remembered that at the Birmingham meeting of the British Association, Mr. Sturgeon read a paper in Section G on the Birmingham compressed air scheme, and an abstract of this paper will be found in our issue of September 24, 1886.

The plant now erected and partly in use at the company's works, which are situated on a triangular piece of land lying between the Midland Railway, the Birmingham and Warwick Canal, and Garrison Lane, comprises three fine sets of air-compressing engines and a corresponding number of boilers and gas producers. The engines are vertical, triple expansion condensing beam engines, with compressing cylinders above, three in a line with the steam cylinders, and three more over the opposite ends of the working beams.

They were made by Messrs. John Fowler & Co. (Limited), Leeds, and each is capable of indicating up to 1,000 horse power. The engines are placed on the ground floor of the spacious engine house, the basement being occupied by the boilers, which are of the Root pattern, fired by gas, which is obtained from a row of Wilson's gas producers. The use of gas producers is an important part in the whole scheme. It is obvious that in any system of power supply to an extensive district the demands for power must be subject to fairly wide fluctuations, and with boilers fired by coal it would be difficult, not to say impossible, to adjust the rate at which steam is generated to that at which the air is required in such a manner as to insure the maintenance of the standard pressure in the air supply pipes at all times, and yet avoid the waste incurred through blowing off steam from the boilers during the time that the consumption of air is smaller than corresponds to the boiler capacity. It is, therefore, necessary to regulate promptly and with great nicety the rate at which steam is generated, and, as such regulation can be easily effected by the use of gaseous fuel, this has been adopted at the Birmingham works.

There are six single-acting air-compressing cylinders to each engine, the trunk piston being worked by short connecting rods in pairs from the three beams, each actuated by one of the cylinders. The valves of the engine cylinders are worked from two rocking shafts overhead, which receive motion from the working beams by means of inclined connecting rods. In air-compressing machinery it is important to thoroughly cool the compressing cylinder in order that the compression may take place isothermally, as this requires a minimum of power, and for this purpose Mr. D. Greig's patent arrangement has been adopted. The compressing cylinder is vertical, and surrounded in its whole length by a water jacket. The delivery valve covers the entire upper end of the cylinder, and the ram at the end of its upper stroke passes slightly beyond the valve seat, thus coming into contact with the valve which rests upon it, until on the down stroke the ram has passed below the valve seat, leaving the valve behind, which is thus gradually brought down on its seat. Water is circulated through the hollow casing of the valve, which thus also assists in cooling the air on its way past the valve. The air is taken in through a filtering trough fixed in the roof of the engine house, and passes through the hollow trunk piston, and through 19 inlet valves 3 in. in diameter set in its upper face, by which arrangement the clearance space is brought down to a minimum. The diameter of the compressing cylinders is 2 ft. 2 in., and each set of 6 compressors is designed for a delivery of 2,000 cu. ft. of air per minute, compressed to 45 lb. above atmospheric pressure.

We are informed by Mr. Sturgeon that in practical work these air-compressing engines have given very favorable results as regards economy. When running at twenty revolutions per minute, only 20 lb. of steam per I. h. p. per hour was required for the engines, while at the full speed of forty-two revolutions the consumption fell to as little as 15 lb. The compressed air is delivered into a vertical cylindrical storage tank made of boiler plate, in which any water in the air is allowed to settle, and can be drawn off from time to time, the dry air passing away from the top of the storage tank into the 24 in. main by which it is conveyed to the town. The present supply of air to the company's customers represents about 300 h. p., and existing small steam engines are used as motors. The company are, however, experimenting with various types of compressed air motors which have been placed at their disposal by the respective makers, with a view to introduce that type which should prove most economical and generally applicable. One of the greatest difficulties with which the company had to contend was the want of a good meter. Large numbers of meters have been submitted, but the errors were found to be so serious, amounting in certain cases to as much as thirty per cent., that none of these meters could yet be definitely adopted. This, however, is a difficulty which will certainly be overcome in the near future, and with the introduction of a good meter the use of compressed air in Birmingham will very materially increase. The company have from the first recognized the necessity of extending their operations, as is shown by the fact that the site selected will accommodate plant for the supply of about 15,000 h. p.—*Industries.*

THE PRODUCTION OF THE ALLOYS OF ALUMINUM AND SILICON IN THE ELECTRIC FURNACE (COWLES' PROCESS).*

By J. H. J. DAGGER, F.C.S., F.I.C.

Historical.—Although aluminum is one of the most widely distributed of the elements, entering into the composition of nearly two hundred minerals, its oxide alumina was regarded as identical with lime until, in 1754, Margraff proved it to be a distinct substance

In 1807, Davy, so successful with the oxides of the metals of the alkalies and alkaline earths, attempted to decompose alumina by the battery, but failed; and it was not until the year 1828 that Wohler, by heating the chloride with metallic potassium, first obtained aluminum as a gray lustrous metallic powder, and eighteen years later in globules not larger than pin heads; from these with extreme ingenuity he determined the principal properties of the metal.

In 1854, Deville (at that time professor of chemistry in the Ecole Normale, Paris), in course of some researches on the chloride, obtained a button of pure aluminum by the decomposition of the chloride with sodium, and on the 4th of February, that year, read a paper describing his discovery before the Academy of Science.

As a result, a committee was formed to carry on experiments, 2,000 francs being granted to meet expenses.

On August 14 he read a second paper before the Academy, exhibiting several bars of aluminum, and caused a medal of the metal to be struck and presented to the emperior.

In March of the next year experiments on a large scale at the imperial cost were instituted at Javel, and on June 18 Deville presented to the Academy, through M. Dumas, large bars of pure aluminum. These experiments are said to have cost the emperor 35,000 francs (1,458*l.*)

Deville's method, modified in details, is still the chief of the chemical methods of preparing aluminum on a commercial scale, and is dependent on the cost of the metallic sodium and the double chloride of aluminum and sodium, which is the compound used in the most important of the present day processes.

Pure aluminum is a highly lustrous metal, white, with a faint tinge of blue in color. It resists the action of air and moisture even at high temperatures, is not blackened by exposure to the action of sulphuretted hydrogen or the alkaline sulphides, and is not attacked by fused niter, nitric or dilute sulphuric acid. It dissolves readily in hydrochloric acid or in solutions of the alkalies.

Its density is but two and one-half times that of water; compared with other metals its density is as follows:

Metal.	Density.	Compared with Aluminum.
Platinum	21·5	8·6
Gold	19·3	7·7
Lead	11·4	4·8
Silver	10·5	4·2
Copper	8·9	3 6
Iron	7·8	2·9
Tin	7·3	2·8
Zinc	7·1	2·8
Aluminum	2·5*	1·0

* Cast metal 2·56. Rolled or hammered metal 2·67.

In a paper read by Mr. W. H. Barlow before the British Association, 1882, its tenacity is given at 12 tons to the square inch, but weight for weight it would equal high class steel, or 36 tons to the square inch. Its elasticity is almost equal to that of silver. Is ductile, can be drawn into very fine wire, and is almost as malleable as gold. Its thermal conductivity is about two-thirds that of copper. Its electrical conductivity is given by Deville as eight times that of iron. Its specific heat is 0·22, it melts at 1,300° F.,† but exhibits no tendency to volatilize, even though heated in a carbon crucible in a blast furnace to high temperatures.

The extreme lightness of aluminum, its power of resisting the action of the air, moisture, and sulphuretted hydrogen, give it an advantage over silver, which it equals in tenacity and elasticity, as a material for jewelry and for scientific and astronomical instruments.

The greatest value of aluminum is as yet in its alloys, and it is with their production in the electric furnace I propose to deal to-day, and I may remark that the successful application of the intense heat of the electric arc to the production of metals on a commercial scale marks a new departure in electro-metallurgy of which we cannot overestimate the importance, rendering it possible to produce rich alloys of aluminum at half the cost of any other process, and so widening the field of their application to an extent hitherto unknown.

* Read before "B" section, British Association, September 13, 1889.

† Bailey gives 700° C. = 1,484° F.

Messrs. Cowles' first experiment was with a very refractory zinc ore containing silver, which they had failed to reduce in an ordinary furnace. A fire clay tube was taken, filled with a mixture of the crushed ore and charcoal powder, a bundle of electric light carbons inserted in each end, and a current from a small dynamo sent through the mass; in a short time the ore was reduced, but the fire clay tube was partly melted, showing the necessity for a lining that would protect the furnace walls from the intense heat.

Powdered charcoal, a very feeble conductor of heat and electricity, was tried, but it was found that after a time it became converted into graphite, thus becoming a conductor, as the smelting proceeded changing gradually from the inside to the outside, and as the hot zone expanded causing loss of energy and eventually destroying the furnace.

Mr. Alfred H. Cowles then suggested soaking the charcoal powder in milk of lime, and drying before use. This proved successful, each particle of charcoal being coated with a film of lime, which insulates it and prevents electric conduction between neighboring particles, even after the charcoal is converted into graphite. Messrs. Cowles now found that they had a furnace that would enable them to conduct metallurgical operations at a temperature hitherto unknown outside the laboratory, and after some experiments with corundum, they, acting in conjunction with Prof. Mabery, set up the first plant for the production of aluminum bronze, ferro-aluminum, and silicon bronze at the works of the Brush Electric Company, Cleveland, O., and on the 20th of January, 1886, Mr. E. H. Cowles read a paper before the Franklin Institute describing the electric furnace and a process of making aluminum bronze.

The Institute thought so highly of the importance of the discovery that they awarded to Messrs. Cowles the "Elliott" gold medal, the highest honor in the gift of the Institute.

The city of Philadelphia awarded them the "John Scott Legacy" medal, this being the only instance of the two awards falling to the same inventors.

In 1887 Mr. E. H. Cowles was elected a Fellow of the Royal Society.

The results obtained at Cleveland were so satisfactory, though using only a dynamo of 300 amperes with E. M. F. of 60 volts, that in 1886 the Cowles Company commenced the works at Lockport, N. Y.

The works at Lockport commenced operations with a Brush dynamo giving a current of 1,600 amperes, with an E. M. F. of 45 to 60 volts; to this have been added two dynamos, each capable of supplying a current of 3,000 to 3,200 amperes with an E. M. F. of 55 to 60 volts. A fourth dynamo is now building, of 3,000 amperes.

One striking feature of the Lockport works is the use of water power, the dynamos being actuated by two powerful turbines, 30 inches diameter = 500 horse power.

The number of furnaces in operation are fourteen, producing about 300 lb. of aluminum contained in alloys per twenty-four hours. Four additional furnaces are now building.

I will now describe the English works of the company at Milton, Staffordshire.

The Milton Works.—These, the first electro-metallurgical works established in Europe, are situated near Milton station, on the North Staffordshire railway, with which system they are connected by a siding, and also abut on a branch of the Trent and Mersey canal, thus affording facilities for cheap transit of raw material, coal, and finished products.

The experience at the Lockport works showed conclusively that great economies were to be expected from increasing the size of the furnaces and the strength of the electric currents, but no current of more than 3,000 amperes had been used up to the time the Milton works were planned.

Mr. Cowles then prepared a specification for a dynamo to give a current of 5,000 amperes at 60 volts, and eventually Messrs. Crompton's designs were accepted.

Dynamo.—This dynamo is of 500 horse power, and furnishes a current of 5,000 to 6,000 amperes with an E. M. F. of 50 to 60 volts. It is said to be the largest machine (at least in regard to quantity of current) in England, and probably in the world. I will not describe this magnificent machine more fully, as it was the subject of a very interesting paper read by Mr. Crompton before the "G" section of the Association last year.

Boilers.—The boilers supplying steam to the works are of the Babcock-Wilcox type, representing 600 horse power, and are fitted with mechanical stokers; by this means one man can easily attend to the generation of steam for the whole works.

Engine.—The main engine, used for driving the dynamo only, is a compound condensing horizontal tandem engine, made by Messrs. Pollitt & Wigzell, of Sowerby Bridge, and is well worth noting for its beautiful workmanship. Its motion is indeed so silent that with your back to it at the moment of starting you cannot tell whether it is in motion or not. It is of 600 horse power, and is provided with automatic expansion gear, and the centrifugal governor maintains the speed at 76 revolutions. It is needless to say that work of this kind involves rapid fluctuations of load, and as an additional precaution against racing, the engine is fitted with Tate's electrical "stop valve," which stops the engine automatically if the speed exceeds a certain limit. It can also be stopped from various points in the engine and furnace rooms by means of push buttons connected in parallel with the main circuit leading to the Tate's valve.

The engine has a 23 in. high pressure and a 43 in. low pressure cylinder. The stroke is 5 ft., the average steam pressure being 85 lb. The flywheel is 20 ft. in diameter, and weighs 20 tons; it is geared to the dynamo by 18 driving ropes, so that the dynamo makes five revolutions for each revolution of the engine.

The Current.—From the dynamo the current is led by the copper bars to an enormous "cut-out," calcu-

lated to fuse at 8,000 amperes. This is probably the largest ever designed, and consists of a framework carrying 12 lead plates, each 3½ in. by $\frac{1}{16}$ in. thick. From this it passes into the furnace rooms. A current indicator is inserted in the circuit, consisting of a solenoid of nine turns. (This was cut out of a cylinder of cast copper by means of a parting tool in a screw-cutting lathe.) In the solenoid is an iron core suspended by a spring. The movement of this is communicated to two pointers, one dial being placed in the engine room and the other in the furnace room. The range of the indicator is such that the entire circle of 360° = 8,000 amperes.

Furnaces.—There are two furnace rooms, each containing six furnaces. The first room contains the bronze furnaces, in which is carried on the manufacture of aluminum copper and silicon copper. The second is devoted to the production of ferro-aluminum. The furnaces are rectangular in form, built of firebrick, the internal dimensions being 60 in. by 20 in. by 36 in. Into each end is built a cast iron tube, through which the carbon electrodes enter the furnace.

Electrodes.—Each electrode consists of a bundle of nine carbons, each 2¼ in. in diameter, attached to a head of cast iron for ferro-aluminum, or cast copper when cupro-aluminum is made. Each carbon rod weighs 20 lb.

Quite recently it has been possible to obtain carbons 3 in. in diameter, weighing 36 lb.; these are employed in bundles of five. The "head" of the electrode is screwed to the copper rods of "leads," which can be readily connected with or disconnected from the flexible cables supplying the current.

Each cable is secured to slides running on omnibus bars of copper overhead, so that it can be brought into position opposite the furnace to be used.

The electrodes are arranged so that it is possible, by means of a handle and screw, to advance or withdraw them from each other in the furnace.

Lining.—Lining the furnace is the first operation preparatory to smelting; this is done by covering the bottom of the trough with a layer of prepared charcoal.

Charcoal Lining.—Oak charcoal is used. This is ground under edge runners, treated with milk of lime, and dried, first in a steam-jacketed revolving drum and afterward on a hot iron plate. Each particle of charcoal is thus coated with an insulating film of lime.

The electrodes are now arranged in the furnace, and a "former," consisting of two pieces of sheet iron connected by stirrups arched so as to fit over the electrodes, forming a box without top or bottom (the size being dependent on the charge used), is dropped over the electrodes. Prepared charcoal is then rammed into the space between the iron sheet and the firebrick walls of the furnace. This done, the charge of ore mixed with coarse charcoal and the metal to be alloyed with the aluminum, in form of turnings or "granules," is placed inside the iron box, after which this is carefully withdrawn. Some broken pieces of carbon are arranged so as to connect the electrodes and start the current. The charge is then covered with coarse charcoal, and the cast iron cover, having a hole in the center for the escape of gases, is lifted into place and luted so as to prevent the entrance of air.

The commencing current is about 3,000 amperes, gradually increasing to 5,000 amperes in the first half hour. The time occupied by a "run" is about one and a half hours. Soon after starting the gases escaping from the orifice in the cover take fire and burn with a white flame.

This gas consists mainly of carbonic oxide, with small quantities of the hydrocarbons and nitrogen. On the conclusion of the run the furnace is allowed to cool, the melted alloy collecting in the bottom of the furnace. The next furnace, ready charged, is connected, so that the process is a continuous one, the furnaces being successively charged and connected.

A form of furnace in which the metal is tapped from the bottom has given very satisfactory results.

The energy required to produce one pound of contained aluminum depends, of course, upon the grade of alloy, the average being 18 horse power per hour.

The crude metal from the furnace is then refined and remelted in a reverberatory furnace, each "run" is sampled, and the percentage of aluminum ascertained by analysis.

The nature of the reaction that takes place in the electric furnace is not very easy to ascertain. The reduction of the ore takes place in an air-tight box, and in the presence of an enormous excess of carbon. It may be assumed that at the intense heat of the electric arc the ore melts and gives up its oxygen to the carbon—

$$Al_2O_3 + 3\,C = 3\,CO + Al_2$$

The presence of copper or iron is immaterial, as the reaction takes place with ore alone, but in absence of the alloying metal the liberated aluminum absorbs carbon and is converted into a carbide.

Prof. Hampe, however, contends that the reaction is in two stages, the first being electrothermic, in which the ore melts; the second, electrolytic, in which electrolysis of the molten oxide takes place, aluminum being liberated.

Supposing an alternating current is used in the furnace instead of the continuous, and that we have a high number of alternations—from recent experiments with alternating currents we know that very slight or no electrolytic action occurs—if then we get equal results, it would go to prove that the action is thermic, and *not* electrolytic.

Alternate Current Experiment.—An experiment was made by the Cowles Company, using an alternating current.

The furnace used was 48 in. × 12 in. × 24 in., with current of 900 amperes with E. M. F. of 50 volts, alternations per minute 11,000. At the end of 1½ hours we obtained 45 lb. of 4 per cent. aluminum bronze.

This investigation was purely of an experimental character, and it cannot be doubted that on the larger commercial scale the result would be more satisfactory.

The results obtained were identical with those given by the continuous current in every way, the resultant slags similar in composition.

The slag from the electric furnace is really only melted unreduced ore, and not a slag in the proper sense of the word. Its approximate composition is Al_2O_3 90, SiO_2 2·00, Fe_2O_3 4·00, CaO 3·9, P 0·10.

The charcoal from the old linings, which has been partially converted into graphite, is recrushed and treated with milk of lime, dried as before, and thus used many times over. The crude metal from the "runs" is remelted with a fluorspar as a flux, and tapped from the reverberatory furnace into ingots or plates, the refinery slag is put into a revolving drum for breaking into pieces, and then washed to remove carbon; the entangled particles of alloy are thus recovered and are worked up with other charges.

These operations are carried out in a separate building, the reclaiming house.

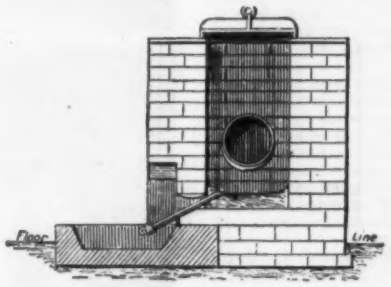
Production.—These works produce about 200 lb. of contained aluminum per twenty-four hours, the most valuable alloy being aluminum bronze, which is supplied in grades* containing 1¼ to 11 per cent. aluminum. To obtain these, the rich furnace product contains 15 to 20 per cent. aluminum is remelted and reduced to the desired percentage with metallic copper and cast in 12 lb. ingots.

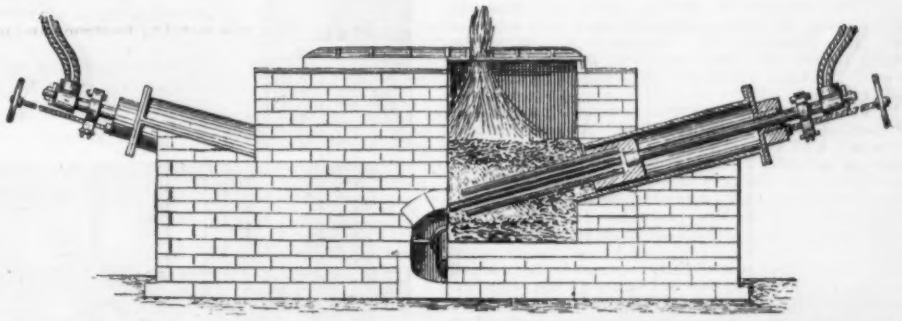
I have now described the most important features of the electro-metallurgical industry as carried on at Milton, and will proceed to describe the chief properties of the alloys produced and some results obtained from them.

The Alloys of Aluminum.—With copper, aluminum forms a series of interesting and beautiful alloys varying in color from bluish white to red, gold, and pale yellow, and also differing widely in physical and mechanical properties.

Alloys containing 60 to 70 per cent. aluminum are very brittle, glass hard, and beautifully crystalline. With 50 per cent. the alloy is quite soft, but under 30 per cent. the hardness returns. The 20 per cent. bronze has a whitish yellow tint, and somewhat resembles bismuth; it is very brittle, and can be pulverized in a mortar.

The brittleness of alloys containing more than 11 per cent. prevents their use, but from 11 to 1¼ per cent. they are of very great value, possessing great tensile strength, high resistance to compression, low specific gravity, and greater resistance to corrosion than any alloy known.





TRANSVERSE AND LONGITUDINAL SECTION OF THE COWLES ELECTRICAL FURNACE.

The following gives the density of these alloys compared with other metals and alloys:

Metal.	Density.
Aluminum bronze, 3 per cent.	8·69
" " 4 "	8·62
" " 5 "	8·37
" " 7·5 "	8·00
" " 10 "	7·69
" " 11 "	7·23
Brass	8·38
Cannon bronze	8·23
Cast bronze	7·20
Cast steel	7·71
Iron	7·80
Nickel	8·57
Silicon	2·67
Platinum	21·50
Gold	19·30
Lead	11·40
Silver	10·50
Copper	8·90
Tin	7·50
Zinc	7·10

Cu_2Al.—The standard "A" grade, containing 10 per cent. aluminum, behaves as a true alloy, that is, will not liquate out into different combinations. It resembles pale gold in color. Its tensile strength in castings runs from 75,000 lb. to 90,000 lb. to the square inch, with from 4 to 14 per cent. elongation.

The high elastic limit in a material so plastic is noteworthy.

In *resistance to compression*† this metal equals the best cast steel; its *transverse strength* or rigidity is about forty times greater than ordinary brass; its limit of elasticity equals steel of the same tensile strength and elongation; forged, tempered, and annealed, its elongation equals the best grades of steel of the same strength.

The "Special" grade contains more aluminum than "A" grade; is higher in tensile, transverse, torsional strength and elastic limit, its elongation is less varying from *nil* to 8 per cent.

The B, C, D, and E grades, containing 7½, 5, 2½, and 1¼ per cent. aluminum respectively, decrease in tensile strength from about 65,000 per square inch in B to 25,000 lb. in E grade. The transverse and torsional strength, elastic limit, and resistance to compression decreasing as the aluminum is lowered, elongation increasing in the same proportion. The E grade metal will stretch nearly two-thirds of its length before rupture, which exceeds that of pure copper by about 100 per cent. A piece of C grade wire can be twisted through several hundred turns before breaking. A rolled bar of C grade (5 per cent.) tested at the Phœnix Works, Rohort, Germany, gave—

Tensile strength..82,880 lb. to square inch, 37 tons.
Elongation .....60 per cent.

All grades of this bronze under 11 per cent. can be rolled, swedged, or drawn cold, and is the only bronze that is not "hot short," and can be worked at a bright red heat as easily as wrought iron. Under the hammer it can be drawn out to the fineness of a needle.

The rolling of sheets, rods, bars, and wire is done at bright heat, only the finishing being done cold. Rolling or working this metal in any way makes it stronger and tougher.

A "rolled" rod "B" grade, tested at the Otis Iron and Steel Works, Cleveland, O., showed tensile strength 83,000 lb. (37 tons) to the square inch, with 39 per cent. elongation before breaking. In the casting this metal had but 60,000 to 65,000 lb. (26·7 to 29 tons) tensile strength, with 20 per cent. elongation.

The fracture of the special and "A" grades exhibit a crystalline structure; the lower grades are extremely fibrous.

The beautiful color and power of resisting corrosive influences make aluminum bronze valuable in art metal work.

In the church of St. Germain, Paris, are 12 beautiful candlesticks, 6 ft. high, and a crucifix, 4 to 5 ft. in height, made of 5 per cent. aluminum bronze; these have been in position over twenty years, and their color is still perfect.

In Philadelphia the statue of William Penn, intended to surmount the dome of the new city hall, will be cast in aluminum bronze.

Aluminum brass is another valuable alloy, made by combining aluminum bronze with zinc in different proportions. It is a close-grained, homogeneous, and tough metal.

The torpedo shell before you is cast from this metal (the No. 2 grade).

This alloy forges hot, and its special casting properties, its resistance to corrosion, its low specific gravity, render it valuable as a material for ships' propellers, stern and rudder frames, pump plungers and rods, valves, wheels, and pinions, and for hydraulic and engineering work generally.

A number of tests were made by order of the Navy Department of the United States of aluminum bronze and brass as compared with United States gun bronze, with favorable results. A blade could be made of it at least one-third thinner than cast iron or any other bronze blade, and would be that much lighter.

For cartridge shells this alloy cannot be equaled; their strength would enable a thinner and lighter shell to be used, with the advantage of not being corroded by the contained explosive. The use of aluminum bronze as a material for cannon was the subject of a paper read before the United States Naval Institute. As early as 1859 a mountain gun of this metal was cast and tested by the committee of artillery of France with very favorable results—the high price of aluminum being then the only thing prohibitive of its widespread use for guns.

Ferro-Aluminum.—The alloys of aluminum and iron have long been known. They are referred to by Faraday, who found 0·013 to 0·69 per cent. aluminum in "Wootz" steel.

Rogers, in an article in the *Moniteur Industriel*, No. 2879. 1859, says a small per cent. of aluminum makes steel hard, strong, and brittle, a larger quantity makes it very dense, without impairing its peculiar polish or detracting from its qualities.

* "High grade" furnace, product 20 to 30 per cent. Al.
† Compression test 156,000. Watertown Arsenal test.

The influence of aluminum in small quantity on cast iron is very marked, and was last year the subject of an interesting paper by Mr. W. J. Keep, in conjunction with Prof. Mabery and L. D. Vorce, of the Case School of Applied Science, Cleveland, O., read before the American Association for the Advancement of Science, August, 1888.

Two bases were used—one a white iron, with composition Si 0·186, P 0·263, S 0·0307, Mn 0·092. The other, gray Swedish iron, marked F. L. M., with Si 1·249, P 0·064, Si 0·04, Mn 0·187. The ferro-aluminum used was made by the Cowles process, and contained Si 3·86, Al 11·42 per cent. Each base was experimented upon separately, and at the same time a series of blank trials were made, the metals in the two series being subjected to exactly the same conditions.

The following results were obtained:

1st. Solidity of castings and prevention of blowholes. The aluminum castings were of a slightly finer grain and of increased solidity. With 0·1 per cent. Al present the resistance to dead weight was increased about 44 per cent., and to impact 6 per cent.

2d. Does the aluminum remain in the iron after remelting? The white base, after the addition of 0·25 per cent. of aluminum, was remelted six times, fresh quantities of the white being added each time. That the aluminum remains in and improves the iron is shown by the superior and stronger castings obtained in this series, even after the percentage of Al had become very low, than in those cases where no aluminum was added.

3d. The effect of aluminum on the grain. Aluminum seems to enable iron to hold in solution all its carbon until just upon the point of solidification, when it is precipitated in a finely graphite form. The advantage of this is the uniformity of the mass and the absence of pockets of graphite, which are generally produced when ordinary gray iron has been cooled slowly. Hence the homogeneity and greater strength of the aluminum castings.

The rapidity of cooling makes little or no difference, as the release of the carbon seems to be instantaneous and only at the moment of crystallization.

A very little aluminum is sufficient to precipitate graphite from white iron, 0·25 per cent. rendering it perceptibly darker in color, 0·5 per cent. more so, while 0·75 per cent. renders it quite gray, with no signs of white.

With increasing amounts up to 4 per cent., the maximum in all these experiments, the effect is the same, the castings becoming softer and grayer as the amount of aluminum increases. The presence of much silicon does not alter the matter, the grain being the same also in thin and rapidly cooled as in thick castings.

4th. Aluminum castings are not affected by chilling. Graphite is liberated whether the casting is cooled rapidly or slowly, with the result that the grain is uniform and there is no chill.

5th. When sufficient aluminum is present to liberate the graphite, a coating is formed on the casting which resists the sand and the heat, and prevents the iron burning the sand into itself.

6th. The fineness of the grain causes them to be more easily cut than cast iron of coarser grain.

7th. The presence of aluminum increases the strength to sustain a constant load, but the strength does not increase uniformly with the percentage of aluminum.

8th. The increase in strength is much greater and more marked than in the preceding. Above a certain percentage the strength diminishes, due to larger amount of graphite liberated.

9th. Elasticity is improved.

10th. The fineness and compactness of iron containing aluminum gives less permanent set than iron equally as soft when that softness is produced by silicon.

11th. The shrinkage is slightly increased with a small quantity of aluminum, due probably to the elimination of blowholes, but with 0·75 per cent. and more it is much decreased, especially in the case of wrought iron.

12th. In case of the white iron, fluidity is much increased. With gray base containing much silicon it is not as clear, though it is believed the fluidity is increased.

The fact that aluminum lowers the melting point of iron is utilized in the Mitis castings, the invention of Mr. Peter Ostberg, of Stockholm. In making Mitis castings, a very small quantity of aluminum, about 0·050 per cent. Al, in form of 7 or 8 per cent. ferro-aluminum, is added to the charge (about 60 lb.) of wrought iron in the crucible the moment this has been melted. The fusing point is at once lowered about 500°, and the charge becomes very fluid and can be cast in the finest moulds, while the great difference between its temperature and its fusing point gives all the time necessary for its manufacture without danger of its solidifying.

The tensile strength of Mitis castings may be as high as 27 tons per square inch, with an elongation of 20 per cent. Another alloy made in the electric furnace is silicon bronze, which, owing to its great strength and tenacity, its resistance to corrosion, combined with high electrical conductivity, is, perhaps, the best metal extant for electric light, telephone, and telegraph wires.

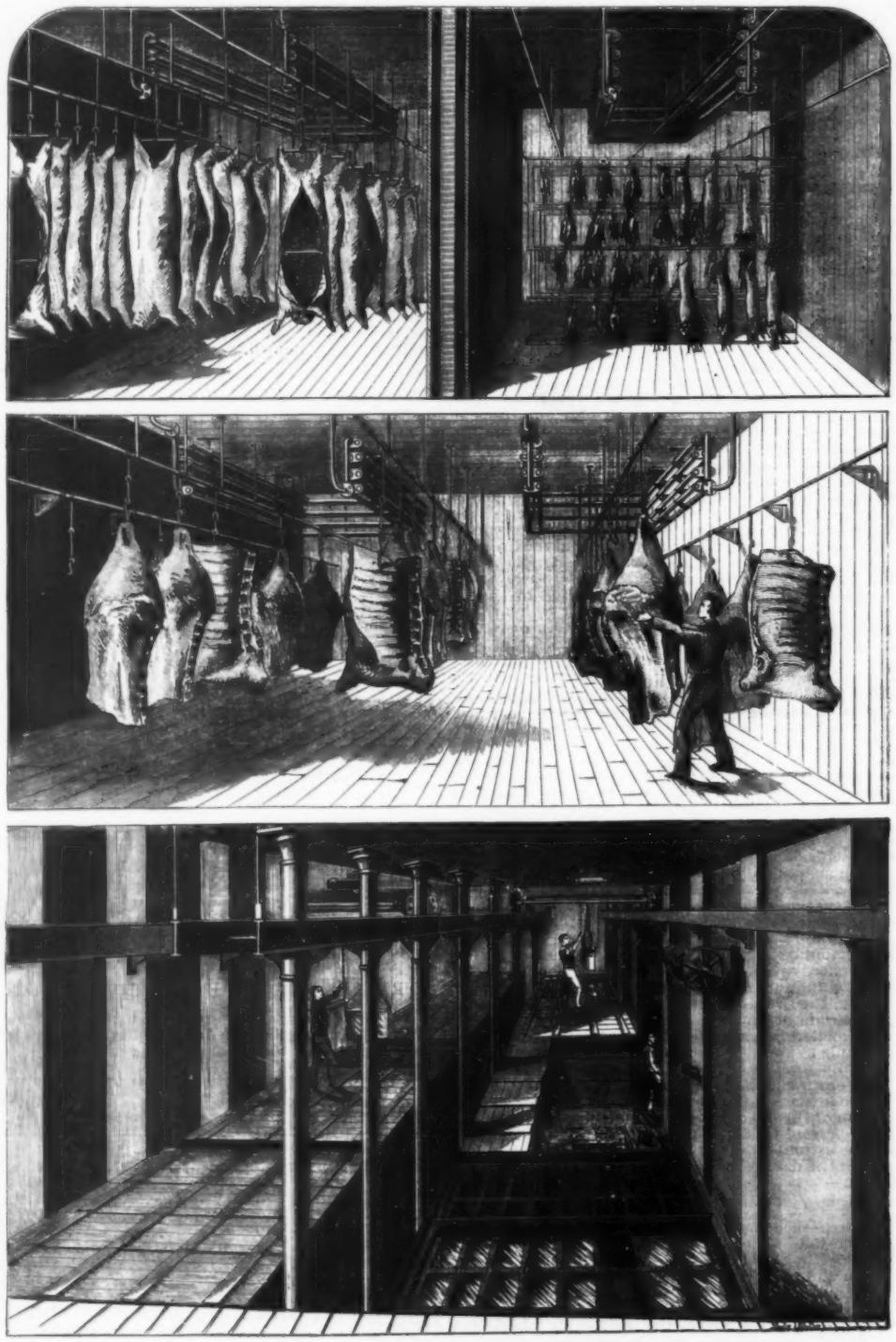
IMPROVED REFRIGERATING MACHINERY.

THE last few years have been remarkable for the great development in the manufacture of ice-making or refrigerating machines, while the extended uses and applications of this class of machinery in the various arts, manufactures, and commercial enterprises, have been still more surprising. This is to be accounted for, no doubt, by the high efficiency to which refrigerating machinery has attained, securing economy in working. We illustrate this week from the *Engineer* portions of an ice-making, cold storage, and meat-freezing plant, supplied to Mr. Burton, wholesale provision, fish, poultry, and game merchant, Nottingham, and erected by Messrs. Pontifex & Wood, of London. The plant consists of two refrigerating machines, together with their appliances, which we propose describing in their order. The refrigerating machine works on the ammonia absorption principle, and is a good example of one of the firm's most modern make, embodying all their more recent and useful patents. We understand that the original plant erected at Nottingham in 1886 consisted of a 9 ton refrigerator—that is to say, a machine of the nominal producing capacity of nine tons of ice per day; but so successful did this machine prove that it was found necessary to quadruple the installation for the following season.

The present capacity of the works is as follows: In the cold storage and freezing room accommodation has been provided for storing from 5,000 to 6,000 sheep or 1,000 quarters of beef, all hanging separately, to allow plenty of air to surround the meat; and in the ice-making department, ice boxes have been put down with capacity for making thirty tons of block ice per day, while a sufficient reserve of power and space has been provided for still further extensions if necessary.

Before describing the refrigerating machine, it may be as well to remind our readers of the physical law that, on the change of any liquid into the gaseous form, with a corresponding increase of bulk, a large amount of heat is rendered latent, and on the reverse operation taking place, the latent heat in the gas is rendered sensible, so that it can be readily removed. The Pontifex patent refrigerating machines work on this principle. Each consists of a number of very strong cast iron cylindrical vessels connected together by pipes and cocks. The large horizontal vessel is called the generator, into which a charge of ammoniacal liquor—that is, commercial liquor ammonia—is put. This vessel contains a coil of steam pipes heated by steam from a boiler, so as to evaporate the ammonia contained in this vessel. The ammonia vapor then rises up a vertical cylinder called the "separator" or "analyzer," placed on the top of the generator. This separator contains a series of cast iron trays fixed at certain distances one over the other, while on their inner surface nozzles are cast, and are so arranged that the ammonia vapor is free to pass upward, while each plate contains a certain quantity of liquid—the introduction of which will be described later on—passing downward, condensing on its way any watery portions that may be ascending with the ammonia, and causing them to return to the generator. This part of the apparatus is one of the chief features of this machine, and is patented by the manufacturers.

From the top of the separator a pipe conveys the gas to the condenser, the latter being the largest vessel shown in the engraving of the refrigerating machine. It is made of wrought iron, and contains a number of coils of pipes, through which the ammonia vapor or gas passes; while outside the pipes the condensing water is made to circulate. The top portion of this condenser is termed the rectifier. Here, at certain intervals, patented pockets or traps are inserted in the coils of pipes, by which means any watery particles that may possibly be passing over with the ammonia gas from the separator are conveyed back to the latter vessel, so that what finally passes from this portion of the apparatus is absolutely anhydrous ammonia—a condition necessary to the economical working of refrigerating machines. This is one of the great advantages claimed by the manufacturers for these machines over all other makers. The ammonia gas is then condensed in the remaining or lower portion of the condenser into a liquid form by the pressure caused by its own accumulation. This liquor is allowed to pass into the cooler, which is a cast iron vessel also containing wrought iron pipes. In this cooler the liquid ammonia, having left the condenser at a temperature of about 70 deg. or 80 deg. Fah., is allowed to expand into the gaseous form. In doing so its sensible heat is rendered latent as above described, and its temperature is ordinarily reduced down to 4 deg. or 5 deg. Fah., or from 27 deg. to 28 deg. below freezing, and often registers —10 deg. Fah., or 42deg. below freezing, while a still lower temperature may be obtained if desired. A circulation of brine—a medium used for conveying the cold to where it is required—is pumped through the coils of pipes in the cooler, and the expanding ammonia gas cools this brine down to any desired temperature. After this the ammonia gas passes away through a pipe into another vertical cylinder, called the absorber, in which it meets with and is absorbed by the water from which it was first evaporated. From this absorber the ammoniacal liquor—this being the name of the liquid at this point—is drawn by the pumps, and is conveyed through the smaller upright vessel fixed on the generator, which is termed the heater or economizer.



COLD STORAGE ROOMS, NOTTINGHAM.

Here its temperature is raised by means of the water which was originally separated from the ammonia, and is finally received in the generator after passing down through the separator—this liquid being that already referred to in the earlier portion of the process.

It ought here to be stated that the plan adopted for economizing the heat by means of the heater is very ingenious, simple, and effective, though we fear that to describe it would occupy more space than we can spare; therefore we pass on to state that the ammoniacal liquor having so found its way back into the generator is evaporated again, and the operation rendered continuous, the same ammonia and water being used indefinitely. The ammonia pumps supplied with this machine are of an entirely new and patented design, being of the double instead of the single acting type as formerly supplied. We understand the new pumps are now used with all Messrs. Pontifex & Wood's machines with great success. We are informed that the stuffing boxes of these pumps have only been packed three or four times since the machine was erected, although it has been working nearly continuously.

Having described the refrigerating machine and its working, we now pass on to the ice boxes in the ice-making department, as shown. These are the Pontifex patent cell ice boxes, and are each capable of making six tons of ice in twenty-four hours, there being five in all. They each consist of a wooden tank provided with two galvanized wrought iron hollow or double bottoms, and two galvanized cast iron hollow main center wall plates with a number of short hollow walls fixed at right angles; these are also of galvanized cast iron. Through the whole of these plates and bottoms the cold brine supplied from the refrigerating machines by means of the brine pumps is made to circulate; while on the outside the water is frozen into large blocks, each weighing about 6 cwt., of pure and beautifully transparent ice. The system has also the advantage of being economical, there being no need of storing up, with all its inevitable waste and great expense, as the manufactured ice need only be purchased by the consumer as required.

During the freezing operation the water is kept continually moving by means of agitators, as shown in the engraving, this being necessary in order to obtain perfectly transparent ice. The ice is got out of the boxes by emptying out the cold brine, and running through the hollow plates and bottoms what is termed "warm" brine; that is, brine which has been previously heated by means of a steam coil supplied with the exhaust steam from the engine, to a temperature of about 60 deg. This relieves the ice from the surfaces of the hollow plates and bottoms, so that its removal is very easy. Indeed, it is interesting to witness the ease and rapidity with which the huge blocks of ice are removed ready for delivery.

Passing on from the ice-making department, we arrive at the cold storage and freezing rooms. These number sixteen in all, most of them being fitted up with wrought iron galvanized cooling pipes with patented connections, through which the cold brine circulates, all supported from the ceilings. This brine usually leaves the refrigerator, as already stated, at about 37 deg. below freezing, enabling the rooms when filled with meat to be easily maintained, if desired, at many degrees below freezing. If hot meat, that is, meat just killed, be placed in these rooms, it is frozen in twelve hours after admission. These rooms are so well constructed that if the machines are stopped working at any time, say from Saturday night to Monday morning, we were informed that a difference of only from 2 deg. to 3 deg. rise in temperature in the rooms is registered.

These cold rooms are used for all kinds of purposes besides preserving butchers' meat, such as the storing of game, poultry, hares, rabbits, butter, lard, bacon, etc., which can kept here for an almost indefinite time, still retaining their freshness in taste and appearance.

We may add that precisely similar machines have been erected at the Avonmouth Docks, Bristol, also at Glasgow, Aberdeen, Portsmouth, etc., with similar results, while a very large number has been erected in breweries, bacon-curing factories, paraffin oil works, butterine manufactories, etc., with equal success. We are informed that Messrs. Pontifex & Wood have received and nearly executed orders for twenty-eight machines during the present season.

Where their machines have been erected for ice making, we are given to understand that ice is made at from 2s. 6d. to 3s. 6d. per ton, this, of course, depending upon the size of the plant—say 60 cents to 80 cents per ton.

FILTERING ARRANGEMENT.

By C. R. GYZANDER.

Chemist, Cochrain Chemical Co., Boston, Mass.

A FILTER support, which is an improvement on the arrangement for rapid filtration described by Mr. R.

FIG. 1.

FIG. 2.

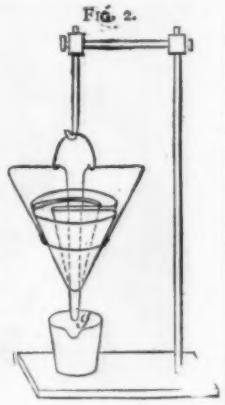


FIG 3.

A. Fessenden in the *Chem. News*, vol. lx., p. 102, is shown in accompanying sketch. It is made from platinum wire, copper wire, or any other suitable material, and bent in the shape shown in Fig. 1.

A paper, folded as described by Mr. Fessenden, is pushed in between the wires, *a* and *b*, Fig. 1, which serves the same purpose as the glass rod, that is, to support the inner folds of the filter; whereas the ring, *c f*, supports the outer folds, giving the whole an appearance of a paper formed with two compartments. This may now be placed in a glass funnel, or used alone simply by suspending it over the beaker as in Fig. 2, the liquid following the wire and dripping from the point, *g*.

As a means of drying precipitates on the filter, it is far superior to the old way of placing the glass found with its filter in the drying oven, as the air has access to the paper from all sides, whereby it dries much more rapidly and thoroughly. For a 7½ inch filter, a support of $\frac{1}{12}$ inch platinum wire, with the ring, *c f*, 2¼ inches in diameter, and the wires, *a* and *b*, 3 inches long, gave excellent service. A glass rod bent as indicated by Fig. 3 works very well.—*Chemical News.*

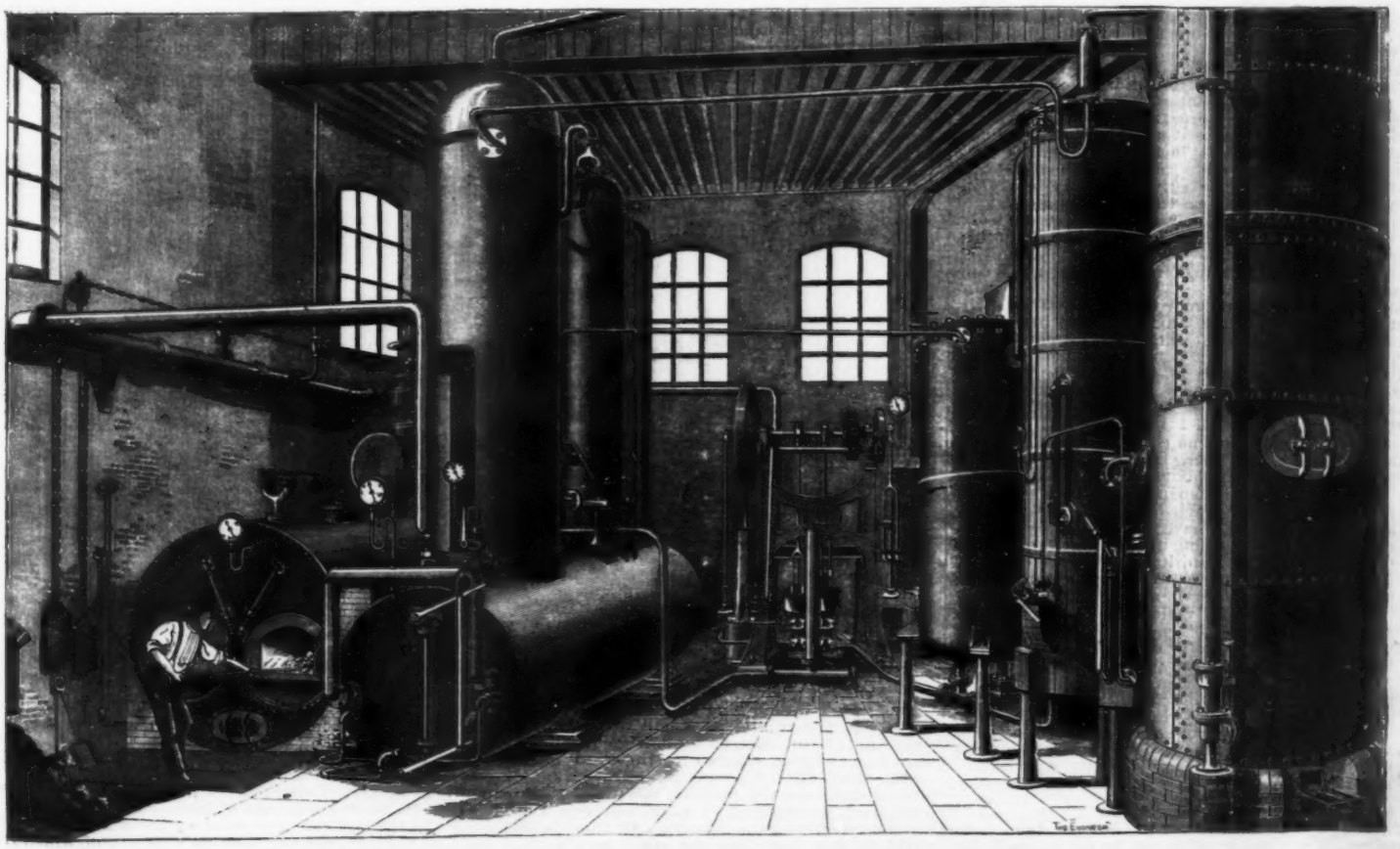
THE MANUFACTURE OF RUBBER CLOTHING.

THE preparation and curing of rubber for heavy clothing is similar to that employed for boots and shoes. The cloth is coated with rubber by the steam calendering machine as for boots and shoes. The same care is necessary to insure perfect dryness and evenness to the cloth. The fabric then passes to the cutting rooms. In the manufacture of gossamer clothing an altogether different process is employed. Instead of being ground up and compounded in the mixing room, the rubber is dissolved with naphtha in a churn made expressly for this purpose. These churns are iron cylinders in which a plunger works in much the same manner as the old dasher butter churn. The mixture is reduced to about the consistency of printers' ink. It is then allowed to run or drop on the cloth, which is rapidly passed under a knife machine or spreader, the rollers of which distribute the compound over the cloth as it passes through.

Thus a web of cloth, the ends being joined together and forming an endless band, is run under the knife from six to sixteen times, according to the kind of goods to be made. Each time the fabric takes a very thin coating of the compound, the naphtha being rapidly dissipated. The cloth is put on rolls and then taken to the curing tables in the open fields, which sometimes occupy acres in extent. With a favorable sun the rubber cloth will be cured in about three hours, and from that up to three days, according to the state of the weather. This process of vulcanizing is known as sun curing, and is not employed for heavy clothing, which is cured in heaters. Some gossamers are also vulcanized that way. In vulcanizing boots and shoes and heavy clothing what is known as dry heat is used, but in all mechanical goods steam heat or live steam is employed.

In making mackintoshes, where the waterproof coating is between the outside of the garment and the lining, the goods are coated on a spreader in the same manner as for the other clothing, but a better quality of rubber is used than on ordinary garments. The goods are then cured by being run over a steam-heated drying surface. The lining is coated with rubber cement and the prepared surfaces of the cloth and lining are joined together by passing them under rollers. By this means they are practically one piece, and skill and experience are required that the goods shall retain their soft, flexible nature and not be rendered stiff and tinny by the layers of rubber.

In making up the garments about 3,500 women and girls are employed by the different factories. The cutting is done by men, and they are also employed in finishing the mackintoshes and a few in other capacities, but the garments are made up by women and girls. The cutting is done in much the same manner as in the manufacture of regular clothing. Several thicknesses of the cloth are laid on a table and cut to pattern at the same time. After cutting, a strip is cemented round the arm sizes and pockets and over the button flap; pieces are also put on where the buttonholes are to come, and all are carefully pressed on by hand rollers. In heavy clothing the seams are cemented and not sewed. Mackintoshes and gossamers are stitched on machines, buttonholes made and buttons sewed on. After being stitched the gossamers are folded up in little bags and are packed in cases for shipment. Mackintoshes, after being stitched, have a strip of cloth cemented over the seams to prevent water coming through the holes made in stitching. The pocket flaps, etc., are then cemented on and the garment is then vulcanized in the heater. This completes it. This final vulcanizing renders them much superior to English goods for standing the extremes of temperature. In finishing heavy rubber surface luster clothing the garments are sponged with varnish and vulcanized by



IMPROVED REFRIGERATING PLANT AT NOTTINGHAM.

being hung in the heaters or dry rooms for about five hours. With dull-finished garments the final process consists in sponging with soap and water, after which the garments are aired and vulcanized.

THE CONSTRUCTION OF BALLOONS.

By CARL E. MYERS.

THE best material for gas balloons will depend upon the size and the use for which they are intended. For models or for a "one-man" hydrogen gas balloon the material should be of the lightest and thinnest fabric procurable, and the theory of construction should be: *The varnish holds the gas, the cloth holds the varnish, and the netting holds the cloth.*

The cloth needs to be only strong enough to support the impervious varnish films, but the netting should be strong and close enough to support all the strain incurred while filling with gas, at which times the strain is unequally adjusted.

Silk is always lighter than cotton or linen of equal strength, and its use is imperative for the smallest models. The silk threads are, however, somewhat like wire, and have fewer fibers or fuzzy filaments radiating from them, as compared with cotton, and the silk fabric resembles a fine wire grating or sieve, while the loose cotton fibers cross the apertures, and so cotton fabrics require less varnish than silk to insure imperviousness.

Cotton fabrics, however, receive or absorb more varnish than silk, if applied with brushes for the first coatings, and the result of numerous experiments was a machine invented by me for "simultaneously coating both sides of a fabric and removing all surplus, for the purpose of rendering it impervious," and which, after several years' private use and experiment, I subsequently patented, and began the commercial production of a so-called "silk substitute" for ballooning and other purposes. This permits the application of repeated coatings of varnish without much increase in weight, and it may be stated that a second point in my system of balloon construction is that *any varnish furnishes an impervious coating if applied in a sufficient number of layers.*

If cotton cloth is used for models it should be finished or bleached cloth, without fuzz, which absorbs varnish and weights the fabric.

For captive balloons or for coal gas balloons the fabric may be any of the lighter grades of unbleached cloth, according to size or strength required.

For hot air balloons the material is commonly "Atlantic A" sheeting for one-man balloon, and heavier grades of cotton sheeting for larger sizes, and the upper half or one third is frequently of two or more thicknesses.

The weight of any material used will depend upon the thickness of the several coats of varnish and their number. I usually apply seven or eight coats by machinery, and afterward two by hand brushes.

The machine varnish is usually much thicker, but all except a smear is removed by the machine. The hand varnish is applied very thin and well brushed to spread.

The hand-varnished balloon usually weighs twice as much as the machine-varnished balloon of equal imperviousness, and its coating is more brittle on account of the resin remaining in the spirits of turpentine used as a medium or solvent of the gum used.

As stated above, any varnish is impervious if used in a sufficient number of layers.

Its base should be of an elastic or flexible nature when dried, and its ingredients should not be liable to spontaneous combustion when applied and dried upon the fabric. Linseed oil *cooked to a gum* is the best material I have tried. Much experience is needed to cook the oil right every time. From two to ten hours' boiling is necessary, according to heat applied, and I have never cooked it just exactly right without spontaneous combustion occurring within the closed kettle after fire was removed from under it. It is a dangerous process, and never should be undertaken indoors. It burned up one large varnish factory near here, and has almost consumed my entire balloon factory once.

Its preparation is a process requiring patience, skill, experience, and some courage. We dread it so much that we only make it once a year, spend a week upon it, and are glad when its malodorous results are attained.

The preparation of balloon varnish is not a matter of receipts, or ingredients used, but of processes, and cannot be given briefly, or result successfully without experience. Tiberius Canallo, in 1785, gives the following receipt for bird lime varnish for balloons, much condensed:

Boil 1 lb. bird lime one hour till it ceases to crackle, then pour upon the whole 3 lb. of linseed oil. Settle twenty-four hours; decant into another pot. Use it warm.

His own receipt is: Boil linseed oil with 2 oz. saccharum Saturni (sugar of lead) and 3 oz. litharge to each ounce of oil, till dissolved, or half an hour. Boil ½ pint of this "drying oil" with 1 lb. of bird lime in a one gallon pot till the bird lime ceases to crackle, in half or three quarters of an hour. Pour on it 2½ pints more "drying oil" and boil one hour, stirring often. Remove the pot from the fire when about to boil over, and stop boiling when stringy.

These special receipts have not been improved, except by discarding everything but the linseed oil, boiled longer, and thinned with spirits of turpentine.

Mixture of glue, glycerine, and slight additions of bichromate of potash have been used for large balloons, also liquid rubber, and various other preparations, which all result in heavy balloons.

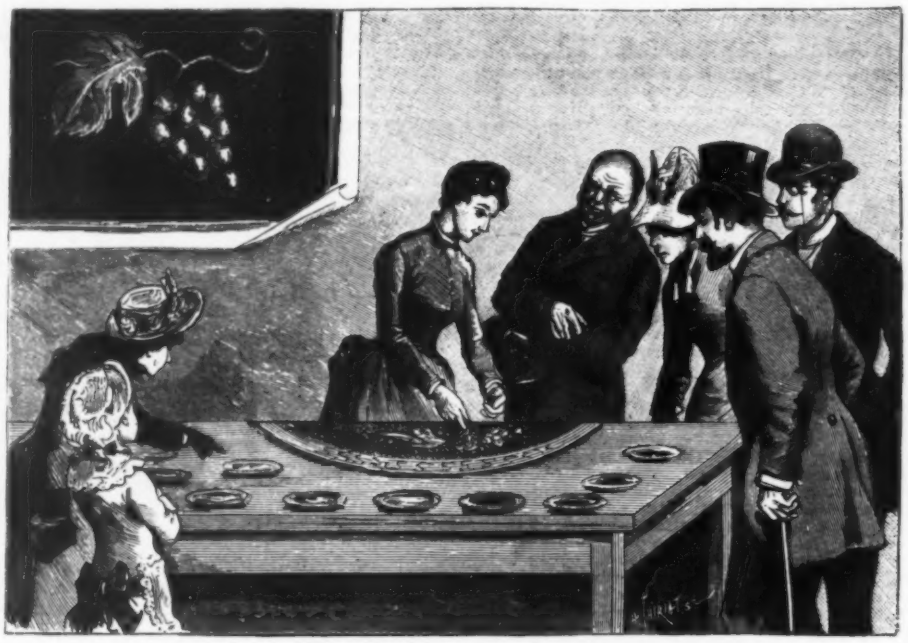
Hot air balloons are usually sized with glue, whiting, or yellow ocher to fill up the pores, and then treated with fireproofing compounds or salt, alum, and sal ammoniac solutions, and quite frequently are sent up with only *smoke* and occasional dashes of salt and water and alum thrown on inside during inflation. All the hot air operations are crude, and frequently result in failure.

CARL E. MYERS,
Frankfort, N. Y. Aeronautical Engineer.

THE supply of natural gas at Auburn, Ind., is decreasing. The number of stoves is limited to 75 this year. Last year 150 stoves could be supplied on the coldest days.

PAINTING IN SAND.

NEAR the Children's Palace on the Champ de Mars, an artist of a peculiar kind, Miss Adele Callebaut, is exhibiting to the public her wonderful talent of sand painting or working with sand. This skillful lady, who is a painter of a new school, has in front of her a series of tin plates filled with specimens of fine sand of various colors. With her right hand she takes this sand and, allowing it to fall upon the table in a regular stream, forms beautiful designs therewith with wonderful rapidity. With violet sand, she represents



PAINTING IN SAND.

a bunch of grapes, and then, with green sand, forms a leaf. Brown sand forms the stalk, and pinches of other sands give the relief and shadows. After this, the artist sweeps away her work and produces a bouquet of roses of a charming aspect; and then carpets ornamented in hundreds of ways. Miss Callebaut succeeds in making the sand fall from her hand with so much precision that she uses it for writing in characters as distinct as though made with an artist's brush.

This exercise in dexterity requires a very delicate hand, and is very curious, and denotes much art and taste on the part of its author.—*La Nature.*

THE PAVILION OF PARAGUAY AT THE FRENCH EXPOSITION.

THE exhibition of the republic of Paraguay is held in an elegant pavilion situated between Suffren Avenue and the Palace of Liberal Arts, on the Champ de Mars. It occupies a total superficies of 2,150 square feet, comprising about 1,500 square feet in covered structures and the balance in gardens.

The order given to Mr. Moreau, the architect, specified that the buildings should be capable of being easily taken down so as to be shipped to Paraguay to be re-erected there. The new structure is to be used at Aruncio, the capital, as a hall for various exhibitions. As this condition on the one hand, and the somewhat small amount allowed for the entire installation on the other, did not permit of erecting a building of large dimensions, the pavilion was divided into three parts, each constructed of wood and iron, the latter being used only for the trussing. Of these three small pavilions, two have but one story and contain the show cases and objects under exhibition, while the third, which is two-storied, is, properly speaking, a sort of belvedere constructed after the type of the miradors that anciently served as observation posts for a watchman who signaled the approach of pirates.

As may be seen, the structure is very simple, and the decoration is not less so, it consisting externally almost exclusively in the arrangement of the wood and of a few mouldings added. In the interior there has been reproduced in paint a few designs borrowed from different public buildings and churches in Paraguay.

The internal arrangement has been studied and carried out with particular care by Mr. Cadiot, the commissioner-general, who has neglected nothing in order to give as much splendor as possible to his exhibit. The products, which are very varied, and in great abundance, may be divided into five categories:

1. Plants.
2. Woods.
3. Minerals.
4. Skins and leathers.
5. Animals.

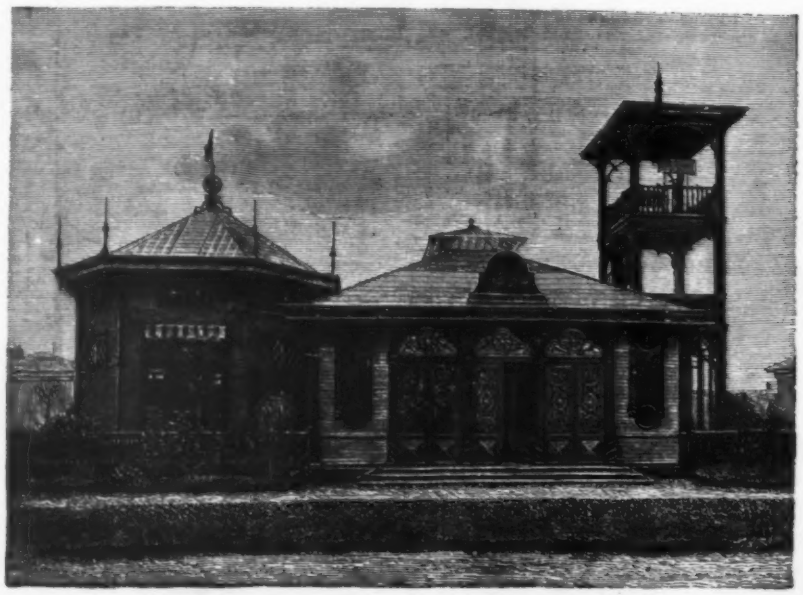
In the first category, let us mention in the first place the *maté*, the leaf of a species of Ilex, of the size of an apple tree, and which, when roasted and reduced to powder, yields a sort of tea, which is extensively used by the people of South America. Alongside of this plant are shown several specimens of Indian corn (the culture of which is a source of riches to Paraguay), cotton plants, and numerous edible and medicinal plants. Among the latter may be mentioned the snakeweed, which, when macerated and applied to the bite of a serpent, or taken in infusion, effects a rapid cure.

In the second category, the most important of all, are shown building and joinery woods, both worked and in the rough, and many objects of turnery.

Minerals are not well represented, not because there are none, but for the reason that the exploitation of the mines has not been pushed to much extent. There are a few specimens of oolitic iron and some rock salt, and that is all.

The skin and leather industry, which is continually extending in measure as cattle raising progresses, has sent numerous specimens of its manufacture. Almost all the skins are tanned with the hair on.

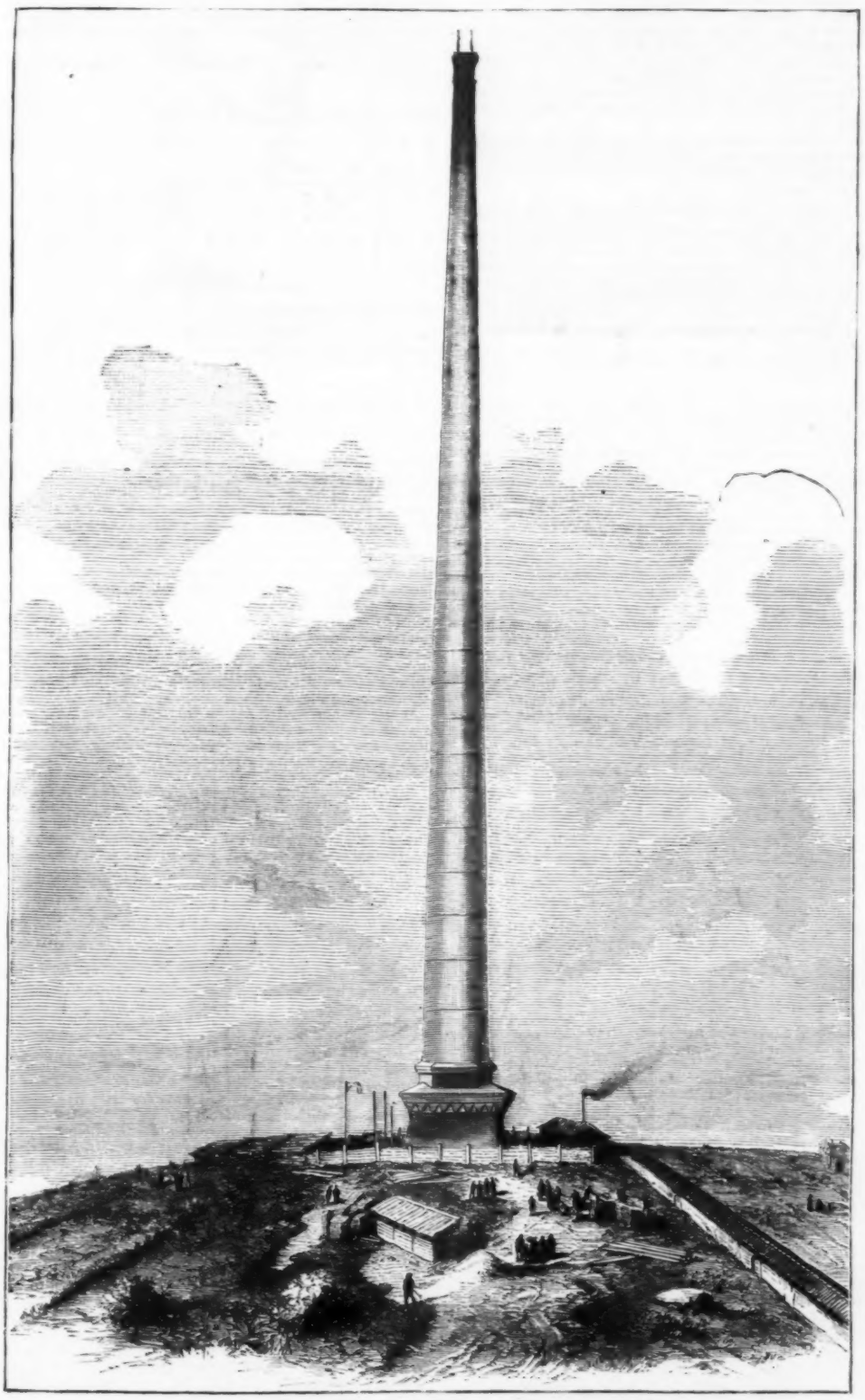
In the last category, most of the animals exhibited are the noxious ones, such as serpents, of which there are more than twenty species in the forests of Paraguay.—*Le Genie Civil.*



THE PAVILION OF PARAGUAY AT THE EXPOSITION.

THE HIGHEST CHIMNEY IN THE WORLD.

AT the Imperial Smelting Works in Halsbrucke, near Freiberg, Saxony, there has been great need of a chimney sufficiently high to carry the noxious gases so far above the surface of the ground as to prevent injurious effects from them; and last year the foundation for the highest chimney in the world was laid there. This chimney is being built from the plans of Huppner, and will be 459 ft. high, with an interior space of 16 ft. It is being erected on the right bank of the Mulde, on ground which is 197 ft. above the works, so that its opening will be 656 ft. higher than the works. The construction has been intrusted to H. R. Heinicke, of Chemnitz, whose special business is the erection of chimneys, in which branch of building he has earned a well deserved fame. The base of the chimney is



THE HIGHEST CHIMNEY IN THE WORLD.

about 39 ft. square, and on this is erected the richly ornamented pedestal, which is 29 ft. high, and from which the round column rises to a height of 429 ft. The transportation of the materials has been very difficult on account of the hilly nature of the land. During the course of construction it is to be mounted by an elevator operated by a portable engine. The expense of building this gigantic chimney will be about $30,000, and it will cost nearly as much to build the exhaust channel from the works to the chimney, a distance of 3,280 ft. It is carried across the Mulde like a bridge, this part of the channel being built of lead and the rest of brick.

That the height of this chimney may be better realized, we will give the height of some other well known structures:

The triumphal column measures about 200 ft.; the church of Notre Dame in Paris, 216 ft.; the Frauenkirche in Dresden, 328 ft.; St. Paul's in London, 364 ft.; the Cheops pyramid, 450; the Strassburg cathedral, 466 ft.; the Cologne cathedral, 531 ft.; the Washington monument, 574 ft.; and the Eiffel tower, 958.—*Illustrirte Zeitung.*

For a table of dimensions of high chimneys in other parts of the world see SUPPLEMENT, No. 720.

[NATURE.]

THE METHOD OF QUARTER SQUARES.*

THE method of quarter squares consists in the use of the formula

$$ab = \tfrac{1}{4}(a+b)^2 - \tfrac{1}{4}(a-b)^2$$

to effect the multiplication of two numbers, a and b. If we are provided with a table giving the values of $\frac{1}{4}n^2$ up to a given value of n, we may obtain, by the aid of this formula, without performing any multiplication, the product of any two numbers whose sum does not exceed the limit of the table.

The method is specially interesting on account of the great simplicity of the formula, by means of which a table of double entry may be replaced by one of single entry. How great a transformation is effected by such a change is evident if we consider that the largest existing multiplication table of double entry reaches only to $1,000 \times 1,000$, and forms a closely printed folio of 900 pages, but that a table of quarter squares of the same extent (*i. e.* of $\frac{1}{4}n^2$ up to $n = 2,000$) need only occupy four octavo pages. The disparity becomes even more conspicuous as the limit of the table is extended, for a table of double entry extending to $10,000 \times 10,000$ would require nearly 100 folio volumes; and one extending to $100,000 \times 100,000$ would require nearly 10,000 volumes; whereas the corresponding quarter-square tables need only occupy 40 and 400 octavo pages respectively.

The use of a table of squares in effecting multiplications was recognized as far back as 1690, when Ludolff published his large table of squares, extending to 100,000. In the introduction of the table Ludolff explained how it could be employed in multiplications. In order to multiply a and b the table is to be entered with $a+b$ and $a-b$ as arguments, and the difference of the corresponding squares divided by 4. If a and b are both even, or both uneven, their sum and difference will both be even numbers, so that $\frac{1}{4}(a+b)$ and $\frac{1}{4}(a-b)$ will be integers. In either of these two cases we may therefore enter the table with the semi-sum and semi-difference of the numbers as arguments, the product being the simple difference of the corresponding squares.

It was not, however, till 1817 that a table of *quarter* squares (*i. e.* of $\frac{1}{4}n^2$ for argument n) was published, for the purpose of facilitating multiplications. If n be uneven, $\frac{1}{4}n^2$ consists of an integer and the fraction $\frac{1}{4}$. This fraction $\frac{1}{4}$ may be ignored in the use of the table, for if either $a+b$ or $a-b$ is uneven, the other is so too; the fraction $\frac{1}{4}$ therefore occurs in both squares, and disappears from their difference. It may therefore be omitted from the table.

The table of 1817, which contained the first practical application of the method, was published by Antoine Voisin, at Paris, under the title "Tables des Multiplications; ou, Logarithmes des Nombres entiers depuis 1 jusqu'a 20,000." It is curious that Voisin should have called a quarter square a logarithm: he called a the root, and $\frac{1}{4}a^2$ its logarithm. His table extended to 20,000, and was thus available for multiplications up to $10,000 \times 10,000$. On the title page Voisin described it as effecting multiplications up to $20,000 \times 20,000$. This statement is justified by the formula

$$ab = 2\left\{\tfrac{1}{4}a^2 + \tfrac{1}{4}b^2 - \tfrac{1}{4}(a-b)^2\right\}$$

by which the product was to be obtained if the sum of the numbers exceeded 20,000, the method of quarter squares being then no longer available. It is to be observed, however, that this formula requires three entries besides the final duplication.

Almost simultaneously (1817) a similar table, of the same extent, was published independently by A. P. Burger at Carlsruhe. The method was rediscovered by J. J. Centnerschwer, who published a table of the same extent in 1825 at Berlin. In 1832, J. M. Merpaut published, at Vannes, a table of quarter squares extending to 40,000. In 1852, Kulik (well known for his large table of squares and cubes to 100,000), who had again rediscovered the method, published a table extending to 30,000. In 1856, Mr. S. L. Laundy published, at London, the largest table of quarter squares which had appeared previous to the publication of the present table. Laundy's table extends to 100,000. It was intended that the multiplications should be effected by means of quarter squares if the sum of the numbers did not exceed 100,000, but other five-figure numbers were to be multiplied by means of Voisin's three-entry formula referred to above.

It is this change of method that has detracted so greatly from the value of Laundy's fine table. It is evident that the table should have been carried to double its actual extent, *i. e.* to 200,000, so that any two five-figure numbers could be multiplied together by means of the two-entry formula. The late General Shortrede constructed such a table, but it was never printed. In the work under notice Mr. Blater carries the table as far as 200,000; so that, more than sixty years after the publication of the first table effecting the multiplication of two four-figure numbers, the extension to five figures has at last been completed.

The method of quarter squares has had no opportunity of a fair trial in the absence of a table extending to 200,000. Considering the many purposes to which Crelle's tables (which give the product of any two three-figure numbers by a single entry) are continually applied, it is perhaps surprising that no general use should ever have been made of a table which, in a very small compass, gives by only two entries the product of two four-figure numbers. Still it is clear that the full power of the method is not felt till we are provided with such a table giving the product of two five-figure numbers. As already stated, the fact that the limit of Laundy's was only 100,000 has deprived it of most of its value, for it is obvious that, unless all five-figure numbers can be treated by a uniform method, the table could not be conveniently employed in practice.

Mr. Blater's work consists of the principal table (giving quarter squares up to 200,000), which occupies 200 pages; a small table of four pages, called the index, to facilitate the use of the table in the extraction of square roots; and an introduction, etc., of fourteen pages. The arrangement of the table (in which the author has followed the plan adopted by Kulik in his table of 1852, already referred to) is somewhat peculiar. The table is first entered (*i. e.* the required page of the table is found) by means of the *last* three figures of the number; the table is then entered on this page (or, more correctly, double page) by means of the preceding figures. For example, the quarter square corresponding to 126,993 is found by turning to the double page headed 990. In one of the four columns headed 993 we enter the table at the line 126: from this line we obtain, in the first column, the first four figures of the result, 4031; in the column under 993, the next three, 805; from the bottom of the column we take the last three figures, 512. The result is therefore given in three parts A, B, C; A being common to ten numbers (in the same line) beginning with 126, C being common to fifty numbers (in the same column) ending with 93, and B being special to the combination 126,993.

The table is beautifully printed in large antique figures on thick and excellent paper, and is a handsome piece of typography. The author mentions that it was entirely set up by a single compositor at the printing office of Mr. Falk, at Mayence, and that it occupied his whole time for eleven months. Besides being admirably printed, the table is no doubt very correct, as a triple calculation was made, and no pains seem to have been spared by Mr. Blater for insuring accuracy.

The book is dedicated to Mr. Anthony Steinhauser,

* "Table of Quarter Squares of all Whole Numbers from 1 to 200,000 for simplifying Multiplication, squaring, and Extraction of the Square Root, and to render the Results of these Operations more certain." Calculated and published by Joseph Blater. London: Trubner & Co., 1889.

of Vienna, who has contributed a short historical preface. Mr. Steinhauser, who is himself the author of several logarithmic tables, encouraged Mr. Blater in his work, and rendered him great assistance throughout. The actual calculation occupied eighteen months.

With respect to the general employment of Mr. Blater's table for the performance of multiplications, is to be feared that its utility has been jeopardized by the size of page adopted. Any one who has occasion to make constant use of tables knows the enormous advantage of the octavo form over the quarto. The book is placed to the left of the computer, and the effort of carrying by the eye a series of figures from the left hand page of a quarto table to the paper—a distance of 18 in. to 2 ft.—is but ill compensated for by large figures or fewer pages. Handsome as the book is to look at, it seems to us that the table would have had much more chance of bringing the method into general use if it had been of octavo form. It is greatly to be regretted that it was not printed on 400 octavo instead of 200 quarto pages, which would have been quite possible with the existing arrangement of the table. If this had been done, and if the type had been somewhat smaller, a neat and handy volume might have been produced.

The mode of entering the table is very insufficiently explained in the introduction. This is unfortunate, as the mode of entry by the last figures is so unusual in tables that it should have been explicitly mentioned. Also the translation into English is so very unsatisfactory as to be obscure in places. These, however, are minor blemishes which would have but slight influence on the general utility of the table, if only the form were convenient.

The question of how far the method of quarter squares is likely to come into use is of some interest. Hitherto the method has been very little known, and so far as we know, it has never been used in practice on any extended scale. The mere fact that it has been so constantly discovered anew is sufficient evidence of the slight attention that it has received. Still there ought to be room for a table that gives, to the last figure, the products of any two five-figure numbers with only two entries. A seven-figure table of logarithms is inadequate for this purpose, for, besides requiring three entries, it only gives the first seven figures of the result.

On the other hand, it may be said that in ordinary calculations seven figures are as many as are required, and that logarithms possess the advantage of being equally convenient for divisions and multiplications. It must be admitted that a five-figure quarter square table is appropriate to only a limited class of calculations: it applies only to multiplications, and the number of figures in each of the two numbers must not be greater than five. These conditions are of a somewhat special kind. In recent years when heavy multiplications have been required it has become the custom to make use of Thomas de Colmar's arithmometer; and probably, at the present time, nearly all systematic work of this character is carried out either by Crelle's tables or by the arithmometer.

Passing now to the general question of multiplication by means of a table of single entry, we have the two methods of quarter squares and logarithms, each possessing its special advantages. There is also an older method which passed out of notice with the invention of logarithms. This method was called "prosthaphæresis," and depended on the formula

$$\sin a \sin b = \tfrac{1}{2}\left[\sin\left\{90^\circ - (a-b)\right\} - \sin\left\{90^\circ - (a+b)\right\}\right]$$

A table of natural sines could therefore be used as a multiplication table, four entries being required. This method is due to Wittich, of Breslau, who was assistant for a short time to Tycho Brahe, and it was used by them in their calculations in 1582. It is referred to by Raymarus Ursus, Clavius, and Longomontanus; and it seems to have been used for performing multiplications not only when the numbers occurred as sines, but also in the case of ordinary numbers.

The method of quarter squares depends upon so simple a formula that it is strange that the first table should not have appeared until 1817. There seems no reason why it should not have been employed before the invention of logarithms, when it would have been a most valuable aid to calculation. The geometrical theorem, which is equivalent to the algebraical identity $(a+b)^2-(a-b)^2=4ab$, on which the method depends, forms Prop. viii. of the second book of Euclid; and one would think that the application of the geometrical or algebraical theorem to arithmetic might have been noticed at any time. The actual history of mathematical tables is, however, entirely different from what we might expect it to have been, owing to the wonderfully early invention of logarithms: and it was, in fact, only just about that time that the importance of tables as an aid to general calculation was beginning to be felt. The date of Herwart ab Hohenburg's great double-entry multiplication table, extending to $1,000 \times 1,000$ (the same limit as Crelle's table, and which has never been exceeded), is only four years earlier (1610) than that of Napier's "Canon Mirificus" (1614).

It is interesting to notice that the method of quarter squares is more closely connected mathematically with the method of prosthaphæresis than with that of logarithms; in fact, from the formula

$$\sin a \sin b = \tfrac{1}{2}\left\{\cos(a-b) - \cos(a+b)\right\}$$

we readily deduce

$$ab = \tfrac{1}{4}\left\{(a+b)^2-(a-b)^2\right\}$$

by expanding the sines and cosines in ascending powers of their arguments and equating the terms of two dimensions.

The method of quarter squares enables us to multiply together two numbers of n figures each if we have a table extending to 2×10^n. If the latter only extends to 10^n three series are required, and the final result has to be doubled whenever the sum of the numbers exceeds 10_n (as in Chaundy's table). If we consider the question of the multiplication of two numbers of n figures each by means of a table extending only to 10^n, the same process being employed in all cases, it appears that three entries are necessary, and that it would be better to tabulate half squares, using the formula

$$ab = \tfrac{1}{2}a^2 + \tfrac{1}{2}b^2 - \tfrac{1}{2}(a-b)^2.$$

In tabulating the half squares the fraction $\frac{1}{2}$ would be thrown off, so that if a and b were both uneven, unity would have to be added to the result.

It would, however, we think, if the table is not to go beyond 10^n, be more convenient to employ a table of triangular numbers. The nth triangular number is $\frac{1}{2}n(n \times 1)$, and if we are provided with a table extending to 10^n, we may multiply any two numbers not exceeding 10^n by means of the formula

$$ab = \tfrac{1}{2}(a-1)a + \tfrac{1}{2}b(b+1) - \tfrac{1}{2}(a-b-1)(a-b);$$

or as we may write it

$$ab = \mathrm{T}(a-1) + \mathrm{T}(b) - \mathrm{T}(a-1-b).$$

T(n) denoting the nth triangular number.*

Thus, to multiply two numbers we subtract unity from the larger number, and enter the table with the larger number so diminished, with the smaller number, and with the difference of these two numbers. For example, to multiply 5289 and 2156, we add the tabular results corresponding to 5288 and 2156, and subtract from this sum the tabular result corresponding to 3132.

The mode of construction of a table of triangular numbers is almost the simplest possible, the numbers being formed by adding to zero the natural numbers 1, 2, 3, . . . *e. g.*

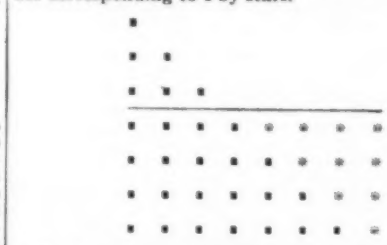
$$0+1=1,\ 1+2=3,\ 3+3=6,\ 6+4=10,\ 10+5=15,$$

and so on. It may be noticed also that any two consecutive triangular numbers are the most nearly equal parts into which a square of points can be divided by a line parallel to the diagonal. For example, in the square of 16 points, the two most nearly equal triangular parts are $1+2+3=6$, and $1+2+3+4=10$. This is shown in the following diagram:

Whether the square contains an even or an uneven number of points, the diagonal, which is in the middle, has to be given to one of the two parts, which therefore necessarily differ by the number of points it contains. In the square n^2, the two consecutive triangular numbers which form it are $\frac{1}{2}n(n-1)$ and $\frac{1}{2}n(n+1)$, differing, as they should, by n, the number of points in the diagonal. Viewing the same matter from a slightly different point of view, we see that any two consecutive triangular numbers always make a square, *e. g.*

$$1+3=4,\ 3+6=9,\ 6+10=16, \text{ etc.}$$

It is interesting to exhibit by means of a diagram the manner in which the rectangle representing the product ab is derived from the three triangular numbers corresponding to $a-1$, b, $a-1-b$. As an example, the mode of formation of the product 8×4 is shown below, the triangular number corresponding to 7 being represented by dots and the triangular number corresponding to 4 by stars.



The dots above the line form the triangular number corresponding to $7-4=3$.†

It is not suggested that the method just described by means of triangular numbers is comparable to that of quarter squares. It is certainly better to double the extent of the table and have but two entries. Still, it is interesting to note how readily a table of triangular numbers extending only to 10^n is available for the performance of multiplications of two n figure numbers. So far as we know, only one extended table of triangular numbers has ever been published. This table, which gives the value of $\frac{1}{2}n(n+1)$ from $n=1$ to $n=20{,}000$, was published at the Hague, by E. De Joncourt, in 1762, under the title "De Natura et Præclaro Usu Simplicissimæ Speciei Numerorum Trigonalium." The book is a small and handsomely printed volume of 267 pages, 224 of which are occupied by the table.

In tabulating quarter squares, the fraction $\frac{1}{4}$ which occurs when the square is uneven is omitted. If we denote by qsq n the tabulated quarter square of n, we have therefore

$$\text{qsq } (2n) = n^2,$$
$$\text{qsq } (2n+1) = n^2+n.$$

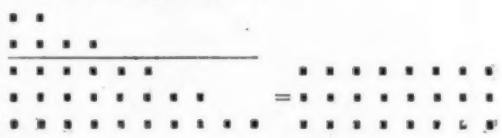
A table of quarter squares may be formed by adding to zero the numbers 1, 1, 2, 2, 3, 3, . . . *e. g.* $0+1=1$, $1+1=2$, $2+2=4$, $4+2=6$, $6+3=9$, $9+3=12$, and so on. Its construction, therefore, is very similar to that of a table of triangular numbers, the only difference being that the added numbers 1, 2, 3, . . . are each twice repeated. We may also regard the tabulated quarter squares as defined by this rule: The quarter square of n is equal, if n be even, to the sum of all the uneven numbers less than n, and if n be uneven, to the sum of all the even numbers less than n. For evidently the series $1+3+5+\ldots+(2n-1)=n^2$, and the series $2+4+6+\ldots+2n=n^2+n$.

By means of this definition of a quarter square we may exhibit the method of quarter squares diagrammatically as follows.

Taking as examples the products 8×8 and 7×4, we have—

$$\text{qsq } 11 - \text{qsq } 5 = 8 \times 3,$$

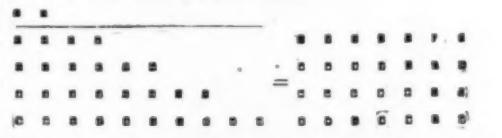
which may be represented by



and

$$\text{qsq } 11 - \text{qsq } 3 = 7 \times 4,$$

which may be represented by



The number of points in the extreme left hand column of the difference of the quarter squares is always equal to the smaller of the numbers to be multiplied. If this number is uneven, there will be one middle line containing a number of points equal to the greater of the two numbers; the points in excess of this number are to be transferred from the line below the middle one to the line next above it, the excess from two lines below is to be transferred to make up the deficiency two lines above, and so on. If the smaller number is even, as in the second diagram, there are two middle lines differing from each other by two points; one point from the lower of these lines is to be transferred to the upper, three points from the line below the lower middle line to the line above the upper middle line, and so on.

It will be noticed that the tabulated quarter squares are, as it were, a species of triangular number in which the succeeding lines of points differ by two, instead of by one, as in ordinary triangular numbers (*i. e.* viewing the matter arithmetically, the quarter squares are derived alternately from the series $1+3+5+\ldots$ and $2+4+6+\ldots$, and the triangular numbers from the series $1+2+3+\ldots$). It is the fact of the lines differing by two which enables us in all cases to adjust the points in the difference of two quarter squares so as to form a rectangle in the manner indicated above.

J. W. L. GLAISHER.

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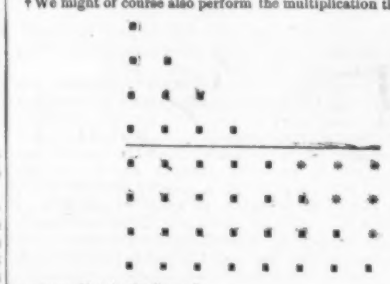
* It is interesting to compare the two formulæ which involve half squares and triangular numbers respectively. In the former case we tabulate a discontinuous function, and in the use of the formula a unit has sometimes to be arbitrarily added. In the latter case we tabulate a continuous function, and the formula always holds good (the larger of the arguments being always reduced by unity). One formula depends on squares, n^2; the other on factorials of the second order, $n(n-1)$.

† We might of course also perform the multiplication thus:



corresponding to the formula

$$ab = \mathrm{T}(a) + \mathrm{T}(b-1) - \mathrm{T}(a-b).$$

But if unity is subtracted from the smaller, instead of from the larger, number, slightly higher numbers are involved in the process.

MAGNESIUM AS A REAGENT.

By H. N. WARREN, Research Analyst.

MAGNESIUM, both on account of its purity and at the same time the speed with which it facilitates reduction, either in the moist or dry way, causes it to rank high, if not the first, among reducing agents. Thus, for instance, on account of its purity from arsenic, no agent is, perhaps, better suited for the elimination of pure hydrogen when using Marsh's test for that substance. Secondly, its absence from iron renders it one of the safest reagents for the reduction of ferric salts previous to titration. The speed of reduction, at the same time, being about three times that of zinc, and giving practically no reaction with potassic ferricyanide, the desired absence of both phosphorus and sulphur may also be relied upon. The ease with which it precipitates, from solutions, for instance, zinc, distinguishes it practically from all other metals, separating the same so perfectly that, if to a solution of zinc acetate containing also metals of the fourth group some pieces of magnesium be introduced, and the solution brought to a state of ebullition, the whole of the zinc is thus separated, so as to cause, after the introduction of the necessary reagents to retain in solution the magnesium salts, no precipitate on the addition of ammonium sulphide.

Several samples of zinc ashes, containing, as impurities, calcium, magnesium, and other carbonates, were quickly assayed by this method, and the zinc estimated in the metallic form.

Its general behavior with iron salts is somewhat more complex, but, strange to say, from a solution containing a chromic salt the iron may, with a slight experience, be entirely separated. Take, for example, a sample of chromeisen, to the acid solution of which has been added a sufficiency of sodium carbonate to replace the combined acid. To the precipitated carbonate is added acetic acid in slight excess; if, now, to the acetic acid solution thus formed about 1 grm. of magnesium is introduced, a somewhat violent reaction takes place, the ferric salt becoming almost instantly reduced, and the reaction thus terminating. On the application of heat to the solution the liquid now changes from the deep green characteristic of chromium chloride to a slight pink, thence to a red, violet, gradually to a pure green, thus assuming its original tint, during which time the iron contained in solution has been precipitated upon the magnesium in a somewhat coherent form, not unfrequently contaminated with oxide of the same. This is to be withdrawn from the solution containing the chromium, boiled with a few drops of HNO_3, and tested for the presence of iron by

means of potassium sulphocyanide. As a reagent in the dry way magnesium reduces all metals with the exception of the alkalies and alkaline earths, and may possibly aid in the decomposition of the latter, provided a suitable combination of the same could be obtained.

As an exception to reduction in this line may be mentioned the powerful manner in which it attacks molybdic anhydride, when fused with the same, the combination being so intense as to be accompanied with loud detonations.

Even the refractory substances silica and boric anhydride may be also reduced when intensely heated in closed vessels with the same.—*Chem. News.*

A TRIP THROUGH THE SEWER IN HAMBURG.

WHILE Hamburg above ground was busy with its exhibition, trying to entertain the crowd of visitors and to win their praise, underground Hamburg wished to do its part, feeling that it also had something worth showing; so the exhibition committee and the department of buildings arranged a number of excursions which would afford an interesting view of part of the immense sewerage system of the city. The trips planned were to be on that branch known as the "Geeststammsiel."

The excursionists gathered at the Lombard Bridge, under which is the spacious "Spulkammer" (Rinsing Chamber). This they examined first. Here the waters of the Alster are dammed up at a level eleven feet higher than the average low water, and five feet above the average high water of the Elbe; and are allowed to escape from time to time so as to wash out the "Geeststammsiel."

Three large boats lighted by torches lay at the underground landing, and these the excursionists entered. The Styx-like weirdness of the trip was increased by the white cloaks and caps which the passengers wore over their ordinary clothing to protect it from dripping water. The boats glided noiselessly through the mysterious darkness, being propelled by short oars.

At regular intervals there were glimpses of the sunny upper world through the shafts, and then torchlights could be discerned again at the sides of the aqueduct, held by mysterious figures that proved to be watchmen standing in niches formed in the wall of the conduit. Suddenly distant, reverberating and strange noises were heard; the gates in the "Spulkammer" had been opened, and the mass of water came thundering and rushing on; but it was some time before it reached the boats. First the foam could be seen at a distance in the half light, and then the large waves raised the boats and carried them on with great velocity. So the strange journey continued until the goal was reached, and gloomy darkness was left for the beautiful daylight. The length of the main conduit—through which the excursionists passed—from the Lombard Bridge to its opening into the Elbe, is nearly two miles; it is circular in cross section, and has a diameter of about ten feet.

The entire system, as completed in 1886, extended over 164 miles and cost more than $4,500,000. The last arms of the system are not yet completed, but the work is being vigorously pushed forward.—*Illustrirte Zeitung.*

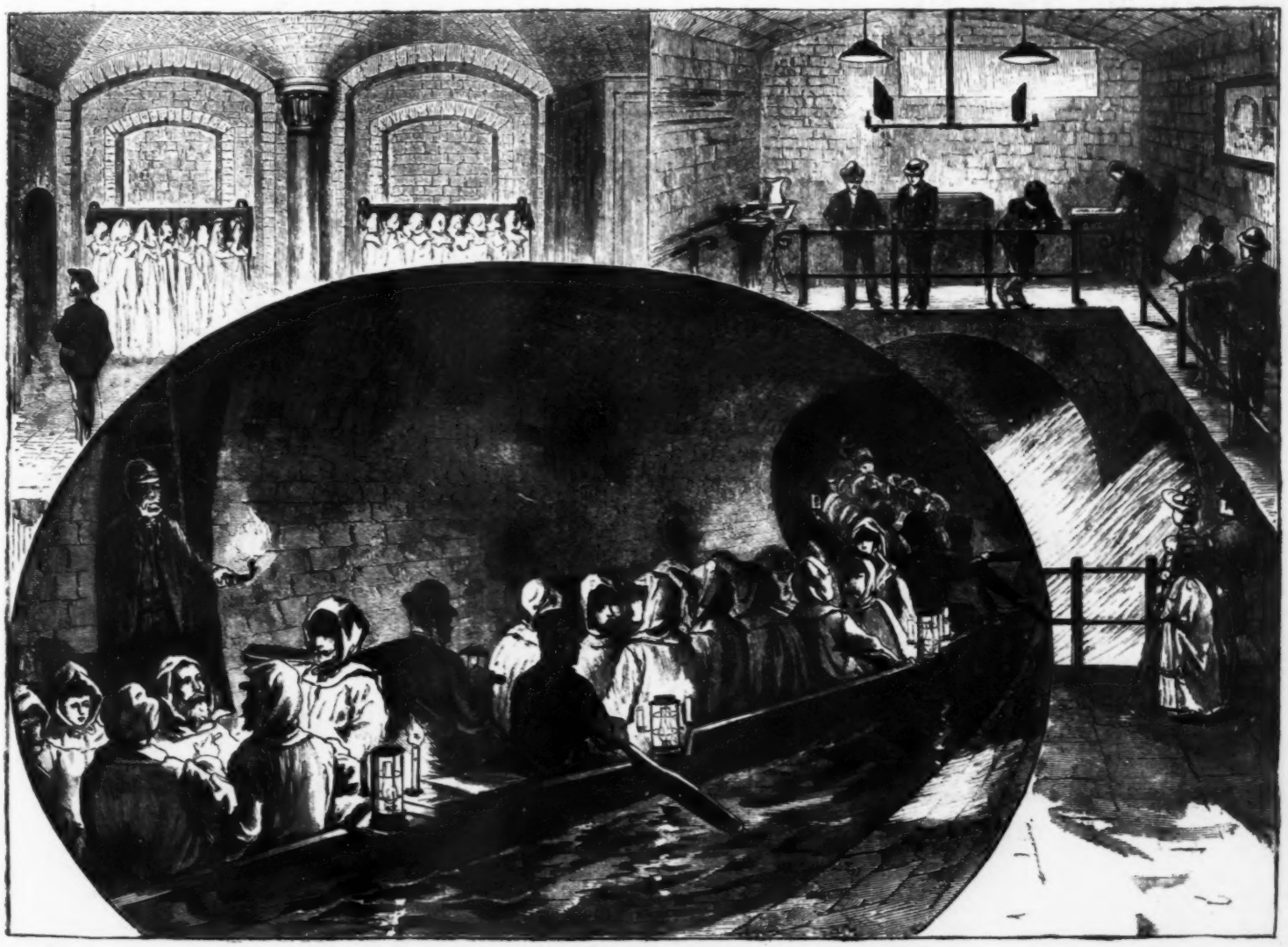
INTERNATIONAL PLACARDS AT THE EXPOSITION.

THE international placards which we have here brought together were one of the curiosities of the exposition, and, with their many-colored tints, enlivened the interminable palisades that took the place of

THE THIRTY-THREE NOTICES OF THE EXPOSITION RAILWAY.

horizon to the travelers on the Decauville railway. They were the piquant note of the trip and exercised the idiomatic faculties of the polyglot visitors. In the first place, at the beginning of the exposition, there was but one warning designed to prevent accidents, the track being necessarily closely hemmed in by the trees of the counter alleys of the Quai d'Orsay. This warning, which was at first placarded in French, was afterward translated into English, Italian and Spanish; and then, as the number of foreigners was constantly increasing, it was found necessary to add new placards reproducing the original notice in Russian, Danish, Swedish, Norwegian, Flemish, etc.

The public was amused at this text reproduced in fifteen different languages, and followed the extension of it with so much pleasure that it was deemed well to add new placards in Arabic, Roumanian, Greek, Turkish, and Chinese, and these were printed in characters so strange that it became necessary to indicate at the bottom what the idiom was that the odd vocables belonged to.—*Le Monde Illustre.*



A TRIP THROUGH THE SEWER AT HAMBURG.

OSTRZEGA SIE

PRZED WYCHYLANIEM GLOWY

POZA OKNO

POLONAIS

FIGYELMEZTETÉS

VIGYÁZAT A FÁKRA

NE TESSÉK FEJÉT VAGY LÁBÁT KITENNI

HONGROIS

POZOR

NA HLAVU A NA NOHY

PRO BLÍZKOST STROMU PODÉL DRAHY

TCHÈQUE

DJAGAR BAIK!

IENGAT POHON

DJANGAN KALOEWAR KAKKIE ATAU KAPALA

MALAIS

CHO KHÉO!

COI CHÙ'NG CÂY CÔI

Đ u'ng giom đâù và gió cà²n ra ngoaì

QUÔC-NG²Ú

ANNAMITE

TANDREMO!

AZA AROSO JOANA NY LOHA

NA NY TONGOTRA NOHO NY HAZO!

MALGACHE

שבור ושברתם באד

שבור ושברתם את בעצים

לא תוצא הכל ולארואש

HÉBREU

ARMÉNIEN

यो
यथा न कथित्पादां
नवा बाहूत्र वा शिरो
वाहनादुत्सनेनरुथयान् ॥

SANSCRIT

اغاجلرون كندوكزى صاقلكز

باسيكزى وياقلريكزى طبشارى

چيقاريكز

TURC

BACATI DE SEAMA!

FERITI-VE DE COPACI

NU SCOATETI PICIOARELE NIÇI

CAPUL IN AFARA DE VAGONE

ROUMAIN

خلي بالك واحترص من

الاشجار لا تخرج رجلك

ولا راسك

ARABE

O CIVES

CAVETE NE CAPVT NEVE CRVRA

VEHICVLO EXSERATIS NE QVIS

ARBORVM OCCVRSV LÆDATVR

LATIN

STÉNOGRAPHIE

SENITÖ!

DLEDOLSÖD BIMIS

NO PLADOLSÖD LOGIS NI KAPI PLÖ VABS

VOLAPUK

THE THIRTY-THREE NOTICES OF THE EXPOSITION RAILWAY.

ATTENTION!

PRENEZ GARDE AUX ARBRES

NE SORTEZ NI JAMBES, NI TÊTE

BRÀVI GÈNT!

AVÍSAS-VOUS DIS AUBRE

E NOUV PASSÉS DEFORO NI LA CAMBO NI LA TÈSTO

PROVENÇAL

OUELLET!

DIHOUELLET DOH ER HOET

TENNET AR DRAN HOU DIHOAR HA HOU PENN

BRETON

CAUTION!

BEWARE OF THE TREES

PUT OUT NEITHER HEAD NOR LEGS

ANGLAIS

КО ВНИМАНІЮ ПУБЛИКИ

Обращайто вниманіе на деревыя

Не выставляите ни головы ни ногъ

RUSSE

WARNUNG!

VORSICHT VOR DEN BÄUMEN

STRECKET WEDER KOPF NOCH BEINE HINAUS

ALLEMAGNE ET AUTRICHE

ATTENZIONE!

GUARDARSI DAGLI ALBERI

NON SPORGER FUORI NÈ LE GAMBE NÈ LA TESTA

ITALIEN

¡OJO!

Cuidado con los Árboles

NO SACAR NI PIERNAS NI CABEZA

ESPAGNOL

ATTENÇÃO!

GUARDAR-SE DAS ARVORES

NÃO ADIANTAR NEM OS PÉS NEM A CABEÇA

PORTUGAIS

WAARSCHUWING!

DENK OM DE BOOMEN

HOOFD EN BEENEN BINNEN

HOLLANDAIS

ΠΡΟΣΟΧΗ

ΠΡΟΦΥΛΑΧΘΗΤΕ ΑΠΟ ΤΑ ΔΕΝΔΡΑ

ΜΗΝ ΕΚΘΕΤΕΤΕ ΤΗΝ ΚΕΦΑΛΗΝ ΣΑΣ
ΚΑΙ ΜΗΝ ΑΠΕΚΤΕΙΝΕΤΕ
ΤΟΥΣ ΠΟΔΑΣ ΣΑΣ

GREC MODERNE

GET OICHT

OP 'T BEM!

STRËCKT DE KAPP AV 'T BËN NET HERAUS

LUXEMBOURGEOIS

OBSERVERA!

AKTA ER FÖR TRÄDEN

STICK EJ UT HUFVUDET ELLER BENEN

SUÉDOIS

OBSERVER

VOGTE SIG FOR TRAERNE

STRAEK HVERKEN HOVED ELLER HODDER UD

NORWÉGIEN

OBSERVER!

PAS PAA TRÆERNE

STIK IKKE HOVED ELLER BENUD

DANOIS

THE THIRTY-THREE NOTICES OF THE EXPOSITION RAILWAY.

[Continued from SUPPLEMENT, No. 725, page 11579.]

INSTRUMENTS FOR MEASURING RADIANT HEAT.*

By C. V. BOYS, A.R.S.M., F.R.S.

LECTURE II.

IN the last lecture I dealt with the subject of instruments which show the effect of heat by the expansion of something, whether a solid, a liquid, or a gas, and showed that while in general these instruments are not capable of showing very feeble effects, yet three of them—Edison's tasimeter, Weber's microradiometer, and Joule's convection thermometer—are, according to all accounts, much more sensitive to the influence of radiant heat than we should be led to expect if we consider the very small coefficient of expansion of bodies for heat. In two of these instruments a change of electrical resistance is the indirect result of the increased temperature of the part of the apparatus exposed to radiation, and in these cases the sensibility simply depends upon the sensibility of the galvanometer that is used in conjunction with the apparatus.

The second class of instruments to which I referred in the last lecture, instruments depending on thermo-electromotive force, are of two kinds, those in which there is a fixed thermo-pile or thermo-junction, which sends a current when it is warm round the needles of a galvanometer, the deflection of which is a measure of the heat poured into the instrument; and, secondly, those in which the thermo-electric circuit is suspended in a strong magnetic field, in which it tends to turn round when a current is sent round the circuit in consequence of the heating of the junction.

The third class of instruments to which I referred are those in which heat changes the electrical resistance of a conductor which is exposed to the radiation, and in which the change of resistance is observed—as in the case of the tasimeter—by means of a galvanometer, either arranged differentially or with a Wheatstone's bridge, so as to obtain the greatest delicacy possible.

All these instruments for measuring radiant heat, which are of an electrical character, require the aid of a galvanometer, or in a few instances they act as their own galvanometer; but in every case they require that a suspending fiber of some kind shall be used, since no pivots that can be made are so devoid of friction as not to completely destroy all chance of observing those minute effects which are within the grasp of the experimentalist.

Since this subject of suspending fibers is of the first importance in nearly all instruments of precision, not only in those which form the subject of these lectures, and since the fibers that are at present in common use all are subject to defects of a very serious character, I feel that I shall not be giving too much time to this part of the subject if I devote the whole of this lecture to its consideration, more especially as I shall be able to show that the annoyance to which the physicist is constantly exposed, owing to the vagaries of his silk suspensions, is no longer a necessity, and that the limit of accuracy, which in many cases is due to the same cause, no longer is determined by the uncertainty of the suspending fiber, but by other causes which, in the presence of silk, are of no account. I shall, therefore, treat this subject of suspension on rather broader lines than I would do if I were merely considering galvanometer construction.

Of all the means that we possess of measuring minute forces, the torsion of a wire or thread is more convenient than any other, because, no matter whether the force to be measured is a mere pull, as in the case of an attraction, or a twist, as in the case of a magnetometer or electrometer needle, torsion may be used, as in the first case, the pull may be applied to the end of an arm carried by the torsion thread, and in the second the turning force or moment may be applied direct.

By means of the torsion of an ordinary piece of brass or German silver wire, a foot long, and as much as 1-50 of an inch in diameter, forces as little as the weight of a single grain can be made evident to an audience. For instance, I have a straw suspended from such a wire, on the end of which I have placed a fragment of sheet iron weighing 10 grains. A weak magnet is incapable of lifting the piece of iron, yet it is able to pull it round through a large angle, and therefore to twist the wire to the same extent. One-tenth of this movement of this straw would be visible to every one in the room, and, therefore, a force as small as the weight of a single grain, a force which, to our senses, is inappreciable, can be made evident with wire as thick as this. If, instead of a plain straw turning round over the table we had a fine index passing over a scale, or, better, a mirror reflecting a beam of light on to a scale, then it would be possible with the same wire to observe the effect of a force a hundred or a thousand times less.

With a finer wire, as is evident, feebler forces may be measured, but it is not at once evident to what extent a fine wire, say one-half the diameter will be more sensitive.

If the wire has half the diameter, it will be sixteen times as sensitive, because $2 \times 2 = 4$, $4 \times 4 = 16$; and so for any other number. The torsion varies as the fourth power of the diameter.

Now, going back to the experiment in which it was shown that with a wire one-fiftieth of an inch thick the torsion was sufficiently small to make it possible to measure forces which to our senses are quite unobservable, forces of one-hundredth or one-thousandth the weight of a grain, it is evident what an enormously increased delicacy would be obtained by using a wire say of one-tenth the diameter—and still finer than this can be obtained in any quantity. In this case, since $10 \times 10 = 100$, and $100 \times 100 = 10{,}000$, the force that would be required to produce a given twist in the thinner wire would be 10,000 times less than is necessary in the thick wire; therefore forces as small as one millionth or one ten-millionth of the weight of a grain would with this simple apparatus be observable.

It was with apparatus such as this, devised in the first instance by Mitchell, an English clergyman, that Coulomb made his famous researches upon the forces between electrified or magnetized bodies, and that Cavendish determined the mass of the earth.

The torsion of such a wire is so small that it might seem at first as if nothing finer could be required; but as a matter of fact, if the needles of an ordinary reflecting galvanometer were suspended by such wire, they would be held so immovably as to make them incapable of responding to such currents as are now easily measured. The forces and moments about which I have been speaking, though they seem very small indeed, are in reality enormous compared with those which can be easily measured. If still finer torsion threads are required, a difficulty is met with. When wire is made much less than one five hundredth of an inch, it begins to suffer in the process of drawing. Copper wire is now made almost one thousandth of an inch in diameter, but this wire is very weak, and difficult to use. I have a specimen of silver wire of this size, given me by Mr. Lecky, which shows well the way in which the surface has been damaged in the process of drawing. As there is a difficulty in showing these fine wires and threads to a number by means of the projection microscope, I have asked Mr. Chapman to photograph for me, with a microscope, the series of wires and threads of which I have to speak to-night, all on the same scale. Photographs perfectly show the appearance that these things present under the microscope, and at the same time they serve most excellently to show the actual size of the several fibers. In the first place, there is a photograph of micrometer (Fig. 2).* Each division is one thousandth of an inch.

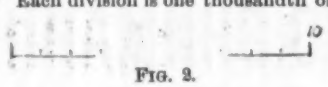


FIG. 2.

I have made corresponding marks on the screen, which will serve as reference marks when other slides are projected upon it. By way of giving some idea of the dimensions, I would point out that this wire to which I have so often referred would, on the scale on which the photographs are taken, completely cover the screen; it would appear about 25 feet wide. The next slide (Fig. 3) is an ordinary human hair, which I show because people speak of a hair as though it were very fine. The next slide (Fig. 4) is a piece of copper wire about one-thousandth of an inch in diameter.

FIG. 3.

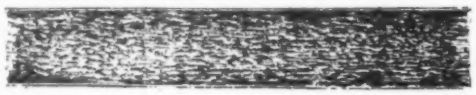


FIG. 4.

Very fine wire is made by Wollaston's process of enveloping a platinum wire in silver and then drawing the compound rod into fine wire, after which the silver is dissolved by nitric acid. There is then left an exceedingly fine wire of platinum, which, however, is, I believe, useless as a torsion fiber. The photograph on the screen (Fig. 5) is taken from a specimen from which the silver has been dissolved only up to a certain place. The end of the silver and the platinum core are evident. This is a two-thousandth of an inch in diameter; it is about the same size as a split cocoon fiber.

FIG. 5.

There is a beautiful material to which I imagine many experimentalists must have turned in their endeavor to find a fine torsion thread. I mean this soft, silky-looking material—spun glass. The photograph (Fig. 6) shows it to be fairly regular, and to be one thousandth of an inch in diameter. This spun glass is a remarkable material in many ways. Experiments made in the physical laboratory at South Kensington by Messrs. Gibson and Gregory show that it is stronger than it ought to be if its diameter only is taken into account. Their results are expressed in dynes per square centimeter, but for purposes of illustration, and because we are familiar with the strength of metals expressed in tons to the square inch, I have put their results in this form. Glass fibers about one thousandth of an inch in diameter have a strength of about 27 tons to the inch. The same glass in rods from twenty to fifty times as thick is from one-third to one-seventh the strength.

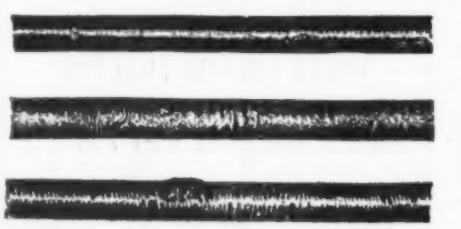


FIG. 6.

Thus it appears that though glass itself will not compare with iron in strength, spun glass has about the same strength as iron. On the other hand, while fine metallic wires are also stronger than they should be, I believe that when they are made as fine as possible the strength does not go on rising, but ultimately falls away again. Thus it is that spun glass is—or rather was until lately—the strongest thing of its size obtainable.

This property of great strength is very valuable, because it makes it possible to suspend larger apparatus, and therefore to obtain larger effects than would be possible with a weaker material; or what comes to much the same thing, a finer fiber will carry a certain apparatus, and therefore there will be a greatly diminished torsion and increased sensibility. Other points in favor of spun glass are its uniformity, its freedom from atmospheric influence, and the fact that pieces of almost any length may be obtained.

There is, however, one very serious defect, which is so pronounced as to make this otherwise splendid material absolutely useless in instruments of precision. Suppose that the thing suspended carries a mirror, by means of which the deflection can be accurately observed. Now it is found that when all has come to rest, if a large deflection is produced by any means, then the zero is changed; the index comes to rest in a new place, and this place is not constant, but slowly approaches the old position of rest. In some experiments which I made two years ago, I found this change of zero to be about 1-430 of the deflection if the mirror were kept deflected for one minnte. Now the fact that the zero is changed every time the fiber is twisted, and that after deflection it is itself variable in position, makes spun glass a useless material for exact work. I may, however, say that I have found that this defect may be partially cured, if the angles of deflection are not large, by annealing the glass in a box of charcoal at a low red heat. In the case of a fiber nine inches long, and turned one complete turn, I found the change of zero after annealing to be about one-sixth of what it was before annealing.

It is partly for this reason, and partly because the torsion of spun glass is still so great, though it is only about one-third of what a brass wire of the same size would have been, if such fine wire were obtainable, that spun glass is never used in the construction of instruments.

There was until lately no means of producing torsion threads finer than spun glass, and therefore the method of using torsion has been abandoned in all the more delicate apparatus, and fibers without torsion have been looked for which might be used to suspend the movable part of the instrument, while some subsidiary means is made use of to direct and give stability to its movement.

The most perfect torsionless fiber that I know of is the spider line. In the paper by the Rev. A. Bennett, to which I referred last week, there is an account of his experiments with spider web. He found that if he magnetized a sewing needle, and suspended it by a piece of spider web two inches long, he could turn the upper end of the web round 800 times, and yet the needle was not deflected to a visible extent. By way of making a more delicate experiment, he heated a piece of fine harpsichord wire in a candle flame, and allowed it to cool in the magetic meridian, so as to obtain a very weak magnet. This hung at the end of a web three inches long, was not moved to a visible extent when the upper end was turned 1,000 times. Finally he attached one fiber of the feather of a goose quill to a piece of web 2½ inches long, and then turned it by a spinning machine more than 1,100 times, but the fiber did not go round. The thread became one inch shorter.

I do not think that much use has been made of spider line, except for cross wires in telescopes, and this is remarkable, for the very elaborate investigations of Joule* show it to be a trustworthy material. Joule experimented on the threads of the diadema spider, which are especially strong. Bennett does not specify the kind of spider that he went to for his threads. The strength of the diadema threads must be very great; Joule found that they were able to carry from 24 to 27 grains before breaking, and that they would carry for an indefinite time a load of ten grains. He also found that with changes of temperature the length of the loaded thread changed also, becoming shorter when warmed and longer when cooled. It also increased in length in a moist air and contracted again in a dry air.

However, the amount of this change is not very great. In a dry air a thread 23 inches long, and carrying 10 grains, would not change in length more than one-sixth of an inch, on an average, for a change of temperature of 100° Fahr. In six months it did not increase by one thousandth of its length. When the dry air was changed for wet air, the filament at once became half an inch longer. The length of diadema web does not seem to be subject to more uncertainty than the length of silk under the same conditions. If this

* Lectures delivered before the Society of Arts, London, 1889. From the *Journal* of the Society.

* The blocks of Figs. 1 to 7 have been kindly lent by the editor of *Nature*.

* Joule's "Scientific Papers," vol. i., p. 479.

diadema thread is as free from torsion as the spider thread used by Mr. Bennett, it would seem to be a perfect material for use in exact instruments. Why it is never* used I am unable to say. Joule speaks as though he used it in his arrangement of dip circle, in which the needle is slung upon two loops of filament; but he says in the description of this instrument that he used silk.

Silk, as produced by the silkworm, consists of a pair of threads gummed together, about a two-thousandth of an inch in diameter apiece (Fig. 7). The silk must

FIG. 7.

be washed in hot water to remove the gum, and the two fibers separated. The single fiber, according to A. Gray,† will carry a weight of about three or four grammes before it breaks, and will safely carry needles weighing from half to one gramme. The strength is approximately 340×10^9 dynes to the square cm., or 22 tons to the square inch. Though finer than spun glass, it is not quite so strong; it has a strength approaching that of ordinary iron. Silk has, until lately, been the material always used in instruments of the highest degree of precision. It has many valuable properties, but it is worse than glass in some respects. The torsion is so small that it is quite a usual thing to ignore it, though, of course, this should not be done in accurate experiments. Gray has given the results of his measures on the torsion of silk. Owing to the irregularity in the diameter, and the fact that it is not round, the figures are subject to a good deal of variation; however, they are worth giving, as they will be useful for purposes of comparison.

He finds that fibers from 0·0009 to 0·0015 centimeter in diameter have a moment of torsion of from 0·00091 to 0·0025 dyne-centimeter units. These measures give as the coefficient of torsion of the silk material numbers ranging from $1{\cdot}39 \times 10^9$ to $0{\cdot}495 \times 10^9$; or a rigidity of $0{\cdot}885 \times 10^9$ to $0{\cdot}316 \times 10^9$ when expressed in C.G.S. units. The rigidity of spun glass, found by Messrs. Gibson and Gregory as the mean of a large number of experiments, is 205×10^9; so that it would appear that glass is from 230 to 650 times as rigid a material as the substance of which silk is made. Joule found that silk behaves much in the same way as spider thread when subject to heat and moisture.

The figures I have given are sufficent to show that the torsion of silk must be very small. Since it has a diameter about half that of spun glass, the torsion on this account would be one-sixteenth; and since the rigidity is so much less as well, the actual torsion is from 4,000 to 10,000 times less. We have already seen that the torsion of spun glass itself is so small that very feeble forces can be measured with it, but the torsion of silk is many thousand times less. No wonder that, since it is also as strong as bar iron, silk is nearly universally used.

It is, or rather was, universally used, because there was nothing better; good as its properties are, minute as its torsion is, I do not know any one who is altogether satisfied with it. The figure which represents its rigidity is true enough, and yet it is hopelessly delusive. Though the torsion, actually, is small, it is not constant, every variation of temperature or of moisture sets some new power in action, so that the position of rest is never the same. This cannot be corrected by increasing the length of the fiber, because the uncertainty of the position of rest may be increased in the same proportion. Finally there is the same kind of elastic fatigue that I have described as making spun glass useless, and in a far higher degree, but the actual disturbing force here is so small that it is sometimes overlooked, though it absolutely prevents any galvanometer from approaching the accuracy that would be obtainable with a perfect fiber.

Mr. Bosanquet, in a short article, ‡ which attracted a good deal of attention at the time, says:

"At certain times the needle of the galvanometer would move about with sudden and capricious movements, the mirror often traversing several degrees of the scale. The decision and sharpness of the movements were very remarkable, and we habitually spoke of their cause as the 'ghost.' The ghost used to visit us mostly in summer, between the hours of nine and eleven in the forenoon and six in the evening; when these movements began, it was no use attempting to work with the galvanometer. There can be no doubt that the movements were due to the solar heat falling more or less directly on the instrument, and causing hygroscopic changes in the silk fiber."

He concludes the article as follows:

"It is my conviction that silk and thread suspensions are sources of error and inconvenience to an extent that has been imperfectly realized; and that they ought to be entirely banished from all instruments of precision."

Mr. T. Gray, § who advocated the use of silk, while admitting that silk is not perfect, employed language which is hardly as strong as the subject deserves. He said:

"When a galvanometer is made sufficiently sensitive for the fiber to play an important part in directing the needle, the set of the fiber, due to continued deflection, always produces an apparent change of zero which, in exact measurements, it is somewhat difficult to properly allow for."

Mr. Gray went on to say that the error is small, except in very special cases, and is in no way capricious. I believe I express the general feeling among experimentalists when I say that the behavior of silk under ordinary circumstances appears, whether it really is so or not, extremely capricious.

Now, having insisted on the defects of the nearly universally employed material, silk, I will next propose the remedy which I described before the Physical Society, ‖ and which my later experience, confirmed by that of others, shows to be a remedy which is complete.

* Mr. Bottomley has told me since these lectures were delivered that he had found the spider line invaluable for suspending the mirror of a very delicate galvanometer.

† "Absolute Measurements in Electricity and Magnetism."

‡ "Phil. Mag.," Dec., 1886.

§ "Phil. Mag.," Jan., 1887.

‖ "Phil. Mag.," June, 1887.

In my experiments on the development of the radiomicrometer, of which I shall speak this day fortnight, I required a torsion fiber finer than spun glass and free from the vagaries of silk. I required a thread with a torsion no greater than that of silk, of great strength, and more perfect if possible than glass or any of the metals in its elasticity. Such a thread, if found, would be valuable not only for my experiments, but for almost all investigations, the accuracy of which is limited by the defects of our present apparatus.

My first endeavors were to make glass fibers finer than spun glass, and I concluded, from my experiments, that the conditions for success were a very small quantity of melted glass, a very high temperature, and the instantaneous production of a very high velocity. These conclusions I tested by the very simple process of attaching a fine rod of glass to the tail of an arrow, and then, when a bead had been melted with the oxyhydrogen jet as large about as a pin's head, shooting the arrow over the longest range that I could conveniently make use of. Under these conditions the bead of glass remains suspended in mid-air under its own inertia, while the arrow goes on its journey; but when the arrow has struck the target, there is found floating in the air, far too fine to fall quickly, a delicate thread of glass, no thicker sometimes than a single spider line. If, instead of glass, a fine rod of melted quartz is fastened to the arrow, held at the free end with the fingers, and heated to the highest temperature attainable with the oxyhydrogen jet, then a thread of quartz can be produced in the same way, and, as you see, the process is perfectly simple and easy. [A quartz fiber was then shot, and its existence made evident by fastening to it a gummed label.]

Now, having obtained quartz threads, it is necessary to describe their properties. In the first place, they can be made as fine as anybody is likely to want them; threads as fine as one ten-thousandth of an inch are perfectly manageable, and can be had in pieces yards long, if required. Threads as fine as one hundred-thousandth of an inch can be made, but are not easy to handle. This will be the more readily understood when I say that a bundle of 10,000 of such threads would be no larger than a single piece of spun glass. How fine the finest ends of some of the fibers that I have made may be, there is no means of telling. Dr. Royston Pigott, F.R.S., believes them to be less than a millionth of an inch in diameter, and I have concluded from their appearance in the microscope—but this is hardly the right expression, for I have not been able to trace them to their end because they are far too fine—that they cannot be much more. These certainly cannot be handled or used as torsion threads. As it is impossible to realize what numbers such as a million really mean, I may say that a piece of quartz one inch long and one inch in diameter would, if drawn into thread one millionth of an inch in diameter, produce more than sufficient to go all round the world 650 times, or an express train, traveling without ceasing, would take thirty years before it could unwind this amount if wound on a reel.

The next quality that I must refer to is the strength of quartz threads. Experiments made with great care by Mr. Highfield and myself in the physical laboratory show that, as in the case of glass, these threads became stronger in proportion to their size as they are finer. A quartz fiber rather finer than spun glass, with a diameter of 6·9-10,000 of an inch, has a strength of 8×10^9 dynes to the square centimeter, or of 51·7 tons to the square inch. A fiber with the diameter of 19-100,000 of an inch has a strength of $11{\cdot}5 \times 10^9$ dynes to the centimeter, or 74·5 tons to the inch. This is a great deal stronger than ordinary bar steel. Thus quartz fibers have the two valuable properties that they can be made as fine as you please and are of enormous strength. We have also found that when the outside of fibers of spun glass or quartz is dissolved with hydrofluoric acid, the strength goes on proportionately increasing as they get finer, showing that in the case of fine fibers the great tenacity is not due to a vitreous skin. Fibers originally of various sizes after being dissolved away till they have the same diameter, have approximately the same strength, which shows that the great strength of fine fibers is not due to their being formed under pressure. (The pressure due to a surface tension equal to that of water would in a fiber one millionth of an inch in diameter be equal to 60 atmospheres, and in thicker fibers less in the same proportion.) These experiments point to the conclusion, not verified in other ways, that there is something analogous to surface tension in the solid fiber.

The next point to consider is the elasticity of the fibers both to stretching and to torsion. Experiments in this direction, I hoped, might throw some light on the cause of the enormous strength of fine fibers. I have on the table the apparatus that I devised for this purpose (Fig. 8).*

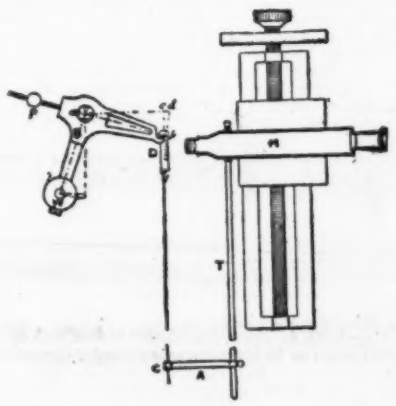


FIG. 8.

The apparatus made by Hilger consists of a microscope cathetometer shown in the figure at M, which can be made to traverse a vertical slide by means of a fine screw having a micrometer head, the divisions of which are capable of being read directly to the one thousandth of a millimeter. To the end of the microscope farthest from the eye piece is attached the vertical tube, T, which carries at its lower end an adjustable arm, A, fitted with a clamp, C. To the end of a separate bracket is fixed the block, *a*, which supports, by means of a knife edge, the beam, B, that is weighted with a gravity bob, W, and carries on a second knife edge, B, the micrometer scale, D, the opposite end of the lever being counterpoised by the adjustable weight, P. The fiber to be tested has attached to it a pin at each end to facilitate its being fixed in the apparatus, it being stretched vertically between the scale, D, and the clamp, C.

When the micrometer head is turned, the cathetometer, M, is lowered, carrying with it the tube, T, and thereby putting a tensile strain on the fiber, which draws down the lever, B, being itself stretched under the increasing pull of the lever. The extension of the fiber is measured by the movement of the scale, D, across the field of the microscope, and the deflection of the lever, B, is a measure of the force that is being applied to the fiber, which is obtained by subtracting the amount of extension of the filament from the distance traversed by the microscope, which latter may be determined with the greatest accuracy by the readings of the micrometer head.

In adjusting the instrument the slide is first made vertical by leveling screws, the accuracy of the leveling being determined by means of a spirit level placed in different azimuths on the top of the micrometer head. The counterweight, P, is next adjusted until the knife edges at *a* and at *b* are both in the same horizontal plane, and this adjustment is made when the scale, D, and the upper attachment pin of the fiber are in their proper position, and the microscope is focused so as to give a sharp definition of the divisions on the scale. The fiber having been attached to the upper supporting pin and suspended in its place, the length of the arm, A, is so adjusted that the lower supporting pin of the fiber hangs freely in the axis of the clamp, C, which is then tightened, and thus perfect verticality at the commencement of the pull is insured. The micrometer head is then slowly turned, readings being taken as each division of the scale, D, traverses and coincides with the cross wire of the microscope, and the force which thus extends the fiber by each increment of one-twentieth of a millimeter is determined in the following way.

If the adjustments of the instrument have been made in the manner described above, the moment due to a vertical pull is proportional to the cosine of the angular displacement of the beam, while that due to the gravity bob and the other portions of the beam varies as the sine of that angle, the actual tensile force applied at D being proportional to the tangent of the inclination of the beam. The vertical distance, *c b*, is a measure of the sine of the inclination, and when the angular displacement is small, this distance is practically the same as the tangent of the angle, and it may be corrected to measure the tangent if very great accuracy be required. The true value of the force corresponding to various values of *c b* may, however, be more easily found by attaching weights to D, and observing, by means of the microscope and scale, the weights which produce corresponding deflections.

In this instrument there are two apparent sources of error, which, however, do not in any way affect the accuracy of the measurement. In the first place, it is evident that as the beam is deflected, the point, *b*, becomes more and more distant from the microscope, and the pull on the fiber ceases to be vertical, but it must be also noticed that in doing so the scale, D, is carried out of the focus of the microscope, which has in consequence to be adjusted by being moved forward to the exact amount which the scale had receded by the movement of the beam, and thus the arm, A, carried by the end of the microscope is moved forward to an equal extent, the scale comes again into focus, and the fiber becomes again vertical.

Again, in the case of the tube, T, being very long, it might happen that the spring of the tube and of the arm, A, might cause the fiber to appear more stretched than it really is, but the error due to this cause can be perfectly eliminated by finding, in the course of the experiment, the force that is being applied to the fiber, and afterward placing weights on C, until a pull of the same amount is obtained. As a matter of fact, however, with ordinary fibers, the further movement of D under these circumstances is not observable.

Messrs. Gibson and Gregory used this apparatus for a very large number of experiments, which they conducted with great care and exemplary patience. They examined fibers both of glass and quartz. The mean value of Young's modulus found for spun glass is $5{\cdot}16 \times 10^{11}$, and for quartz about 6×10^{11}. The modulus of torsion was observed in the usual way, with the following results: Spun glass, $3{\cdot}22 \times 10^{11}$; quartz, $3{\cdot}74 \times 10^{11}$. The rigidity (obtained by dividing these figures by $\frac{1}{2}$) is for spun glass $2{\cdot}05 \times 10^{11}$; for quartz, $2{\cdot}38 \times 10^{11}$.

There seems a good deal of variation between different specimens, but these figures go to show that the elasticity of spun glass is much the same as that of glass in mass, and that quartz is very slightly stiffer than glass.

The only serious fault of glass fibers is the fatigue, which I experimentally showed in the early part of this lecture. I shall now perform the same experiment with quartz, and it will at once be evident that the fatigue of quartz, if it exists, is nothing in comparison with that of glass. As a matter of fact, this fatigue does not cause a change of zero of 1-50 of the corresponding change in the case of glass, and it may be less, but practically it is quite beyond our power of observation to detect any effect with such deflections as are met with in the practical use of instruments.

Quartz, then, has these properties. It is, when in fine threads, stronger than the metals, and so a finer thread of this material will carry a greater weight than can be made of any other material. The torsion of quartz is but little more than that of glass and is less than a third of the torsion of steel, therefore the small torsion due to a very fine fiber is made smaller still on this account. Then, since it is practically free from fatigue, since it is not affected by moisture in the air, nor liable to all the vagaries for which silk is so famous, and since it may be easily made in pieces of

* The block of this figure has been kindly lent by the editor of *Engineering*.

almost any length, there is no reason why silk should still be used. I have now for some time been making, experiments with quartz fibers that would have been, as far as I know, quite impossible with silk, without meeting with any trouble, and to me it seems, in the light of my experiments, to be unwise to use silk in instruments of precision. I may add that I am not trying to find a market for anything of mine, for these fibers are not patented—they are free to the world to use.

As an inventor or discoverer is apt to form too favorable an opinion of anything that he may have done, I shall refer to the experience of others with quartz threads.

Professor Threlfal has found it possible to improve the galvanometer by various modifications until it is from 100 to 1,000 times as accurate and delicate as a measuring instrument as any that can be made in the usual way. It was only when he used quartz that he was able to make any real advance. With silk instead of quartz his instrument was practically no better than any other. This experiment I particularly value because he was very skeptical as to the truth of what I had said about the value of fibers of quartz.

Professor J. Viriamu Jones writes: "You may indeed say that I find the quartz fibers an advantage after silk. I could not get in my low resistance galvanometer (with an ordinary Elliott needle) a constant zero with a period of oscillation of three or four seconds; with your fiber I can get constancy with a period of at least twenty seconds. It has always seemed to me that in a very weak field a galvanometer needle suspended by silk indicates that the silk twists and untwists in the most unreliable and variable manner. Your fiber, on the contrary, in the weakest field I have put the needle in, maintains constancy of equilibrium. . . . You are a benefactor of mankind."

These are not the only instances in which my experience has been fully confirmed by others. It is in consequence of these independent opinions that I have ventured to express myself in the way that I have with regard to silk.

There is another property of quartz fibers and rods which may be found to be of some importance. A stick of clean quartz in a damp atmosphere is an almost perfect insulator, while a piece of glass is, judged by the behavior of the leaves of gold, an almost perfect conductor. Not only may quartz be used in a damp air, it may even be dipped in water, and gold leaves may be hung on it immediately, when it will be found to insulate just as well, even though the water is still visibly clinging to it.*

This high insulation of quartz, even in a wet place, may make it possible to construct electrostatic measuring apparatus which will always be ready for work, and in which sulphuric acid need not be used. But here I am leaving my subject. Going back to quartz threads, it is a curious fact that the ends of many of these become highly electrified in the process of manufacture. Whether it is the friction in passing through the air, or whether it is electrification produced in the oxyhydrogen flame, I do not know, but the fact remains that the floating ends of some of these threads are very highly electrified, and the electricity, small in amount on account of their extremely small capacity, is absolutely unable to escape, but it makes its existence evident in a very curious way. The ends of these fibers, as seen floating, often assume a spiral or wavy form, and these screws serve as excellent instruments for revealing the presence of electrification, which I believe is too small in quantity to show on any apparatus. If you gradually approach the hinder end of one of these electrified screws, it suddenly shoots itself out, and the fiber is projected on to the approaching body. This may be repeated several times.

It is for this reason, I believe, that it is possible to gather the extraordinary material which you now see upon the screen. If you take a strong oxygen hydrogen jet, and keep joining and separating two sticks of quartz in the flame, a very great length of a complex cable is shot away, but it is so fine that it will float away and be lost. If, however, you place in the line of the flame, but a foot or two away, a retort stand or other convenient support, you will find this covered with long threads of this multiple cable, consisting of fibers of all sizes, from one five-thousandth of an inch downward. By varying the size of the flame, the proportion of the gases, and the place at which the quartz is held, you can produce anything between this complex cable down to those fine tapering tails which no microscope can follow to the end.

The following hints may be of use to those who are going to mount apparatus upon fibers for the first time. Having chosen a fiber of the right diameter, and longer than is ultimately required, the first thing to do is to fasten a small fragment of gummed stamp paper to one end. This acts as a weight, and makes the following processes more easy. The upper or fixed support must next be fastened to the free end of the fiber. I prefer a common blanket pin passing through a cork to any of the more elaborate contrivances in common use; however, what is going to be used for the fixed support should be pointed at the lower end.

If the needle or other thing to be supported is very light, *i. e.*, nowhere approaching the breaking weight of the fiber, shellac varnish is the best thing to use as the cement. Just moisten the last five millimeters above the pin with this varnish, and—holding the fiber near its free end in one hand, and the pin in the other, with the little finger of one hand resting against the little finger of the other, for the sake of steadiness—immediately apply the fiber to the varnished surface, to which it will stick. Then pull it endways through a distance of half a millimeter about, to make sure that when all is dry there will be no sudden bend in the fiber. A hot piece of wire, or knife, or pair of pliers must then be applied to the pin above the varnish, so that the heat may be conducted down slowly to drive off the remaining alcohol and melt the shellac. After this the fiber is securely held at that end.

If the thing to be supported is very heavy, varnish is not so good as melted shellac, but this is much more difficult to apply. The pin must be warmed and smeared near the joint, and while hot the fiber must be applied and slightly pulled. Whether varnish or melted shellac is used, it is essential to work in a proper light. A table in front of a large window in the day, or supporting one or two movable gas burners at night, will do perfectly, provided that a really black background exists, upon which the fiber may be made evident. Black velvet, or paint, or paper is no use whatever. The only background that does well, and one that is easily arranged, is the darkness inside a drawer just pulled out an inch or two.

Assuming that one end of the fiber is properly fastened, the next thing is to determine the exact length required. For this purpose I always make a drawing on a perfectly clean and smooth board, showing the point of the pin at one end, the extreme end of the thing to be supported, and the position of the mirror or whatever determines the length of the fiber.

The holding pin is then raised up until the paper weight is hanging in the air. This is then allowed to rest on the board, and slowly dragged along until the point of the pin is exactly over the corresponding mark on the board, and the paper wafer is in the line of, but beyond, the other mark. The fiber is then straight and must pass over the mark which indicates the upper end of the apparatus that is to be suspended, though, of course, nothing can be seen. A knife is then drawn across the board, say five millimeters beyond this mark. By this means the fiber is cut, and the five millimeters are left for the purpose of attachment. The needle or suspended thing is then fastened in the same way as the pin. It is well then to drag the needle along until the mirror is exactly over its place on the drawing, and see if the upper pin is also in its place. By warming either pin, and pulling the fiber, a slight alteration can be made if necessary.

The paper weight with the remainder of the fiber may then be taken up, and the free end fastened on a microscope slide and labeled, so that the diameter of the fiber may at any time be found. If the fiber, illuminated by a distant light, had been examined with a prism first, and the dark bands of the spectrum had been found straight and uniform from one end to the other—and it is only such fibers that I use—then the diameter must be the same over the whole length.

Though I have given a large proportion of the time at my disposal to this one part of the subject, I hope that it will not be considered that I have occupied more time than is demanded by the importance of the subject or the value of the results, of which some are now published for the first time.

* "Phil. Mag.," Aug., 1889.

CONSTANT FOCUS AND DEPTH OF FOCUS IN PHOTOGRAPHIC LENSES.

By WILLIAM A. CHEYNEY.

SINCE the introduction of detective cameras we have heard and read much about lenses having a fixed or constant focus for all objects at all distances from the lens, from four feet upward, and this has led to claims being made, for the lenses of different manufacturers, which have been surprising and at variance with all known laws of optics.

This condition of affairs induced me to make a series of experiments, with a number of lenses made by different manufacturers, in order to convince myself as to what extent these statements could be relied upon. The result of which I give you, as follows:

There is no such thing as a constant focus for any lens; the plane of absolute sharpness varies for every point at which the object may be between an infinitely distant point and the lens.

That there is a plane of absolute sharpness, in all well corrected lenses, there can be no question, and the determination of this plane only depends upon the extent to which the image on the ground glass is magnified.

There is, however, a distance through which the ground glass may be moved, and yet the error in the sharpness of the image cannot be detected by the human eye. This distance varies inversely as the ratio of the diameter of the aperture of the lens (the diameter of the opening in the diaphragm used) to the equivalent focus of the lens (the distance from the optical center of the lens to the ground glass, when an object infinitely distant would give an absolutely sharp image).

This grows out of the fact that the human eye cannot detect an error in sharpness when the error is not greater than $\frac{1}{100}$ of an inch.

To illustrate this, I present Fig. 1.

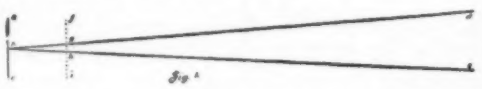


Fig. 1.

Here we have the cone of light from a lens working with an aperture of $f/8$ represented by the lines $b\ d$ and $b\ e$ and the position of the plane of absolute sharpness by the line $a\ b\ c$ (being the position of the ground glass). Now, when the ground glass is pushed up to the position indicated by the line $f\ g\ h\ i$ we have what would be a mathematical point at b, increased to a blurred spot having a diameter represented by the line $g\ h$, and whenever the length of this line $g\ h$ is $\frac{1}{100}$ of an inch or less, it will be impossible for the unaided human eye to detect the error.

But I stated before that this movement of the ground glass varies inversely as the ratio of the diameter of the aperture of the lens to the equivalent focus thereof, and in order to show this, I will call your attention to Fig. 2, given below.

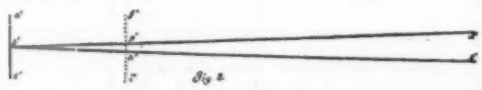


Fig. 2.

In this figure we have the cone of light from a lens working with an aperture of $f/16$, and the conditions are the same as in the former example, excepting that, while the line $g'\ h'$ is equal to the line $g\ h$, it will be twice as far from the point b' as $g\ h$ was from the point b.

Now, these conditions are true for a point back of the ground glass.

Here let me say that this distance from the point in front of the ground glass to the one behind it, between which the error in sharpness is inappreciable, gives rise to what is known as depth of focus in a lens, which is here shown to vary according to the ratio between the diameter of the aperture and the equivalent focus of the lens, and which depends for its existence upon the inability of the human eye to detect the error.

This accounts for the fact that our beautiful little negative, in which we have taken advantage of all the depth of focus of our lens, when it comes to be enlarged gives an unsatisfactory picture. Why? Because we have enlarged the error of focus until the eye is able to detect it.

Still there are some of us who do not desire to make enlargements from our negatives, and for the benefit of those I will go further with the results of my experiments.

I found the following rule to be true by actual experiment with lenses of nine of the most reliable manufacturers, as well as by computation:

Multiply the diameter of the aperture of a lens by the equivalent focus thereof; divide the product by the greatest imperceptible error, and to the quotient add the equivalent focus. The sum will be the distance of an object upon which a lens should be accurately focused in order that all objects beyond a point one-half of the above distance shall be apparently in focus.

Thus let f equal the equivalent focus, a equal the diameter of aperture, and e equal the greatest allowable error; then d will equal the distance of an object upon which, if the lens be accurately focused, all objects beyond $d/2$ will apparently be in focus:

$$\frac{a \times f}{e} + f = d.$$

Or, say we are using a lens with an equivalent focus of eight inches and the $f/8$ diaphragm, then we have

$$\frac{1 \times 8}{\frac{1}{100}} + 8 = 2{,}008 \text{ inches} = 167 \text{ feet } 4 \text{ inches}.$$

Now, if we focus upon an object 167 feet 4 inches from the lens, all objects beyond 83 feet 8 inches will be in apparent focus.

Or, again, if we use a lens the equivalent focus of which is four inches, and use the $f/16$ diaphragm, we have

$$\frac{\frac{1}{4} \times 4}{\frac{1}{100}} + 4 = 254 \text{ inches} = 21 \text{ feet } 2 \text{ inches}.$$

And here, if we focus on an object 21 feet 2 inches from the lens, then all objects beyond 10 feet 7 inches will apparently be in focus.

As the result of the foregoing, I give the following table:

Equivalent Focus in Inches.	Diaphragm.	Distance of Object Focused Upon.	All Objects in Focus Beyond.
8	f/8	167 ft. 4 in.	83 ft. 8 in.
8	f/11·31	125 " 8 "	62 " 10 "
8	f/16	84 "	42 "
7	f/8	126 " 1¼ "	63 " 5⅛ "
7	f/11·31	94 " 8¼ "	47 " 4⅛ "
7	f/16	63 " 4⅛ "	31 " 8⅛ "
6	f/8	94 " 3 "	46 " 1½ "
6	f/11·31	70 " 9¾ "	35 " 4⅞ "
6	f/16	47 " 4⅞ "	23 " 8¼ "
5	f/8	65 " 6¼ "	32 " 9⅛ "
5	f/11·31	49 " 3⅛ "	24 " 7⅛ "
5	f/16	32 " 11⅝ "	16 " 5⅛ "
4	f/8	42 "	21 "
4	f/11·31	31 " 3 "	15 " 7½ "
4	f/16	2 " 2 "	10 " 7 "
3	f/8	23 " 8¼ "	11 " 10⅛ "
3	f/11·31	17 " 10⅛ "	8 " 11⅛ "
3	f/16	11 " 11⅝ "	5 " 11⅛ "
2	f/8	10 " 7 "	5 " 3½ "
2	f/11·31	7 " 11¾ "	3 " 11⅞ "
2	f/16	5 " 4½ "	2 " 8¼ "

By an examination of the foregoing table, two facts are seen: (1) That, while the focus shortens in an arithmetical progression, the distance of the object in focus decreases geometrically, thus showing the reason that short focus lenses have a greater depth of focus than those of long focus; and (2) that the distance to the object in focus decreases directly as the diameter of the diaphragm is smaller, thus demonstrating the cause of the increase of depth of focus by the use of smaller diaphragms.

And, finally, you should know that the lenses used in these experiments were of the kinds known as rectilinear or moderate angle, wide angle, and landscape, or single combination lenses.

Cheyney, Pa., October 10, 1889.

—*Jour. Fr. Inst.*

ATMOSPHERIC ELECTRICITY.

OBSERVATIONS by Professor Leonhard Weber by means of kites and balloons. The kite had carried one end of a wire up with it into the air, the other end of the wire being connected to a galvanometer whose other pole was connected to earth. All the experiments referred to had been made on bright summer days, when there had been no clouds, these having been found to have a very disturbing influence. It was found that the greater the height of the kite, the more intense was the current in the wire, as a general rule, but plotting a curve of currents and altitudes, it was found to have a negative value up to one hundred meters, after which its positive value grew greater with the height above the ground. The negative electrification of the lower strata of the air the writer attributed to the presence of germs and dust particles of various kinds. The rate of increase of electrical potential with the distance from the ground was very rapid.

THE promoters of the Tower Company, limited, which has been organized for the erection of a tower in London, of not less than 1,200 feet in height, offer two prizes of 500 guineas for the best and 250 guineas for the second best design of such a tower. The estimates are to show the weight of material, cost of lifts, and cost of erection. The designs and estimates are open to all competitors and must be sent in on or before the end of February next.

GLACIAL GEOLOGY.*

By Prof. JAMES GEIKIE.

THE president of this section must often have some difficulty in selecting a subject for his address. It is no longer possible to give an interesting and instructive summary of the work done by the devotees of our science during even one year. So numerous have the students of geological science become, so fertile are the fields they cultivate, so abundant the harvests they reap, that one in my present position may well despair of being able to take stock of the numerous additions to our knowledge which have accumulated within the last twelve months. Neither is there any burning question which at this time your president need feel called upon to discuss. True, there are controversies that are likely to remain unsettled for years to come, there are still not a few matters upon which we must agree to differ, we do not yet see eye to eye in all things geological. But experience has shown that as years advance truth is gradually evolved, and old controversies die out; and so doubtless it will continue to be.

The day when controversies shall cease, however, is yet, I hope, far in the future; for should that dull and unhappy time ever arrive, it is quite certain that mineralogists, petrologists, paleontologists, and geologists shall have died out of the world.

Following the example of many of my predecessors, I shall confine my remarks to certain questions in which I have been specially interested. And in doing so I shall endeavor to steer clear, as far as I can, of controversial matters. My purpose, then, is to give an outline of some of the results obtained during the last few years by Continental workers in the domain of glacial geology.

Those who are not geologists will probably smile when they hear one declare that wielders of the hammer are extremely conservative—that they are slow to accept novel views and very tenacious of opinions which have once found favor in their eyes. Nevertheless, such is the case; and well for us that it is so. However captivating, however imposing, however strongly supported by evidence a new view may appear to be, we do well to criticise, to sift the evidence, and to call for more facts and experiments, if such are possible, until the proofs become so strong as to approach as near a demonstration as geologists can in most cases expect such proofs to go.

The history of our science, and indeed of most sciences, affords abundant illustration of what I say. How many long years were the views of sub-aerial erosion, as taught by Hutton and Playfair, canvassed and controverted before they became accepted! And even after their general soundness had been established, how often have we heard nominal disciples of these fathers of physical geology refuse to go so far as to admit that the river valleys of our islands have been excavated by epigene agents? If, as a rule, it takes some time for a novel view to gain acceptance, it is equally true that views which have long been held are only with difficulty discarded. Between the new and the old there is a constant struggle for existence, and if the latter should happen to survive, it is only in a modified form. I have often thought that a history of the evolution of geological theories would make a very entertaining and instructive work.

We should learn from it, among other things, that the advance of our science has not always been continuous—now and again, indeed, it has almost seemed as if the movement had been retrograde. Knowledge has not come in like an overwhelming flood, like a broad, majestic river, but rather like a gently flowing tide, now advancing, now retiring, but ever, upon the whole, steadily gaining ground. The history I speak of would also teach us that many of the general views and hypotheses which have been from time to time abandoned as unworkable are hardly deserving of the reproach and ridicule which we in these later days may be inclined to cast upon them. As the Scots proverb says, "It is easy to be wise behindhand." It could be readily shown that not a few discarded notions and opinions have frequently worked for good, and have rather stimulated than checked inquiry. Such reflections should be encouraging to every investigator, whether he be a defender of the old or an advocate of the new. Time tries all, and each worker may claim a share in the final establishment of the truth.

Perhaps there is no department of geological inquiry that has given rise to more controversy than that which I have selected for the subject of this address. Hardly a single step in advance has been taken without vehement opposition. But the din of contending sides is not so loud now, the dust of the conflict has to some extent cleared away, and the positions which have been lost or maintained, as the case may be, can be readily discerned.

The glacialist who can look back over the last twenty-five years of wordy conflict has every reason to be jubilant and hopeful. Many of those who formerly opposed him have come over to his side. It is true he has not had everything his own way. Some extreme views have been abandoned in the struggle—that of a great Polar ice sheet, for example, as conceived of by Agassiz. I am not aware, however, that many serious students of glacial geology ever adopted that view. But it was quite an excusable hypothesis, and has been abundantly suggestive. Had Agassiz lived to see the detailed work of these later days, he would doubtless have modified his notion, and come to accept the view of large Continental glaciers which has taken its place.

The results obtained by geologists who have been studying the peripheral areas of the drift-covered regions of our continent are such as to satisfy us that the drifts of those regions are not iceberg droppings, as we used to suppose, but true morainic matter and fluvio-glacial detritus.

Geologists have not jumped to this conclusion—they have only accepted it after laborious investigation of the evidence. Since Dr. Otto Torell, in 1875, first stated his belief that the "diluvium" of North Germany was of glacial origin, a great literature on the subject has sprung up, a perusal of which will show that with our German friends glacial geology has passed through much the same succession of phases as with us. At first icebergs are appealed to as explaining everything; next we meet with sundry ingenious attempts at a compromise between floating ice and a continuous ice sheet. As observations multiply, however, the element of floating ice is gradually eliminated, and all the phenomena are explained by means of land ice and *Schmelz-wasser* alone.

It is a remarkable fact that the iceberg hypothesis has always been most strenuously upheld by geologists whose labors have been largely confined to the peripheral areas of drift-covered countries. In the upland and mountainous tracts, on the other hand, that hypothesis has never been able to survive a moderate amount of accurate observation. Even in Switzerland—the land of glaciers—geologists at one time were of opinion that the bowlder clays of the low grounds had a different origin from those which occur in the mountain valleys.

Thus it was supposed that at the close of the Pleistocene period the Alps were surrounded by great lakes or gulfs of some inland sea, into which the glaciers of the high valleys flowed and calved their icebergs—these latter scattering erratics and earthy *debris* over the drowned areas. Sartorius von Waltershausen* set forth this view in an elaborate and well illustrated paper. Unfortunately for his hypothesis, no trace of the supposed great lakes or inland sea has ever been detected. On the contrary, the character of the morainic accumulations, and the symmetrical grouping and radiation of the erratics and perched blocks over the foot hills and low grounds, show that these last have been invaded and overflowed by the glaciers themselves. Even the most strenuous upholders of the efficacy of icebergs as originators of some bowlder clays admit that the bowlder clay or till of what we may call the inner or central region of a glaciated tract is the product of land ice. Under this category comes the bowlder clay of Norway, Sweden, and Finland, and of the Alpine lands of Central Europe, not to speak of the hilly parts of our own islands.

When we come to study the drifts of the peripheral areas, it is not difficult to see why these should be considered to have had a different origin. They present certain features which, although not absent from glacial deposits of the inner region, are not nearly so characteristic of such upland tracts. I refer especially to the frequent interstratification of bowlder clays with well bedded deposits of clay, sand, and gravel; and to the fact that these bowlder clays are often less compressed than those of the inner region, and have even occasionally a silt-like character. Such appearances do seem at first to be readily explained on the assumption that the deposits have been accumulated in water opposite the margin of a continental glacier or ice sheet; and this was the view which several able investigators in Germany were for some time inclined to adopt.

But when the phenomena came to be studied in greater detail, and over a wider area, this preliminary hypothesis did not prove satisfactory. It was discovered, for example, that "giants' kettles"† were more or less commonly distributed under the glacial deposits, and such "kettles" could only have originated at the bottom of a glacier. Again, it was found that preglacial accumulations were plentifully developed in certain places below the drift, and were often involved with the latter in a remarkable way. The "brown coal formation" in like manner was violently disturbed and displaced, to such a degree that frequently the bowlder clay is found to underlie it. Similar phenomena were encountered in regions where the drift overlies the chalk—the latter presenting the appearance of having been smashed and shattered—the fragments having often been dragged some distance, so as to form a kind of friction breccia underlying the drift, while large masses are often included in the clay itself. All the facts pointed to the conclusion that these disturbances were due to tangential thrusting or crushing, and were not the result of vertical displacements, such as are produced by normal faulting, for the disturbances in question die out from above downward. Evidence of similar thrusting or crushing is seen in the remarkable faults and contortions that so often characterize the clays and sands that occur in the bowlder clay itself. The only agent that could produce the appearances now briefly referred to is land ice, and we must therefore agree with German geologists that glacier ice has overflowed all the drift-covered regions of the peripheral area. No evidence of marine action in the formation of the stony clays is forthcoming—not a trace of any sea beach has been detected. And yet, if these clays had been laid down in the sea, during the retreat of the ice sheet from Germany, surely such evidence as I have indicated ought to be met with. To the best of my knowledge the only particular facts which have been appealed to, as proofs of marine action, are the appearance of bedded deposits in the bowlder clays and the occasional occurrence in the clays themselves of a sea shell. But other organic remains are also met with now and again in similar positions, such as mammalian bones and fresh water shells. All these, however, have been shown to be derivative in their origin—they are just as much erratics as the stones and bowlders with which they are associated. The only phenomena, therefore, that the glacialist has to account for are the bedded deposits which occur so frequently in the bowlder clays of the peripheral regions and the occasional silty and uncompressed character of the clays themselves.

The intercalated beds are, after all, not hard to explain. If we consider for a moment the geographical distribution of the bowlder clays, and their associated aqueous deposits, we shall find a clew to their origin. Speaking in general terms, the stony clays thicken out as they are followed from the mountainous and highlying tracts to the low ground. Thus they are of inconsiderable thickness in Norway, the higher parts of Sweden, and in Finland, just as we find is the case in Scotland, Northern England, Wales, and the hilly parts of Ireland. Traced south from the uplands of Scandinavia and Finland they gradually thicken out as the low lands are approached. Thus in Southern Sweden they reach a thickness of 48 meters or thereabout, and of 80 meters in the northern parts of Prussia, while over the wide, low-lying regions to the south they attain a much greater thickness—reaching in Holstein, Mecklenburg, Pomerania, and West Prussia a depth of 120 to 140 meters, and still greater depths in Hanover, Mark Brandenburg, and Saxony. In those regions, however, a considerable portion of the "diluvium" consists, as we shall see presently, of water-formed beds.

The geographical distribution of the aqueous deposits which are associated with the stony clays is somewhat similar. They are very sparingly developed in districts where the bowlder clays are thin. Thus they are either wanting, or only occur sporadically in thin irregular beds, in the high grounds of Northern Europe generally. Further south, however, they gradually acquire more importance, until in the peripheral regions of the drift-covered tracts they come to equal and eventually to surpass the bowlder clays in prominence. These latter, in fact, at last cease to appear, and the whole bulk of the "diluvium" along the southern margin of the drift area appears to consist of aqueous accumulations alone.

The explanations of these facts advanced by German geologists are quite in accordance with the views which have long been held by glacialists elsewhere, and have been tersely summed up by Dr. Jentzsch (*Jahrb. d. konigl. preuss. geologischen Landesanstalt fur* 1884, p. 438). The northern regions, he says, were the feeding grounds of the inland ice. In those regions melting was at a minimum, while the grinding action of the ice was most effective. Here, therefore, erosion reached its maximum—ground moraine or bowlder clay being unable to accumulate to any thickness. Further south melting greatly increased, while ground moraine at the same time tended to accumulate—the conjoint action of glacier ice and subglacial water resulting in the complex drifts of the peripheral area. In the disposition and appearance of the aqueous deposits of the "diluvium" we have evidence of an extensive subglacial water circulation—glacier mills that gave rise to "giants' kettles," chains of subglacial lakes in which fine clays gathered, streams and rivers that flowed in tunnels under the ice, and whose courses were paved with sand and gravel. Nowhere do German geologists find any evidence of marine action. On the contrary, the dovetailing and interosculation of bowlder clay with aqueous deposits are explained by the relation of the ice to the surface over which it flowed. Throughout the peripheral era it did not rest so continuously upon the ground as was the case in the inner region of maximum erosion. In many places it was tunneled by rapid streams and rivers, and here and there it arched over subglacial lakes, so that accumulation of ground moraine proceeded side by side with the formation of aqueous sediments. Much of that ground moraine is of the usual tough and hard-pressed character, but here and there it is somewhat less coherent and even silt-like. Now a study of the ground moraines of modern glaciers affords us a reasonable explanation of such differences. Dr. Bruckner* has shown that in many places the ground moraine of Alpine glaciers is included in the bottom of the ice itself. The ground moraine, he says, frequently appears as an ice stratum abundantly impregnated with silt and rock fragments—it is like a conglomerate or breccia which has ice for its binding material. When this ground moraine melts out of the ice—no running water being present—it forms a layer of unstratified silt or clay, with stones scattered irregularly through it. Such being the case in modern glaciers, we can hardly doubt that over the peripheral areas occupied by the old northern ice sheet bowlder clay must frequently have been accumulated in the same way. Nay, when the ground moraine melted out and dropped here and there into quietly flowing water, it might even acquire in part a bedded character.

The limits reached by the inland ice during its greatest extension are becoming more and more clearly defined, although its southern margin will probably never be so accurately determined as that of the latest epoch of general glaciation. The reasons for this are obvious. When the inland ice flowed south to the Harz and hills of Saxony, it formed no great terminal moraines. Doubtless many erratics and much rock rubbish were showered upon the surface of the ice from the higher mountains of Scandinavia, but owing to the fanning out of the ice on its southward march, such superficial *debris* was necessarily spread over a constantly widening area. It may well be doubted, therefore, whether it ever reached the terminal front of the ice sheet in sufficient bulk to form conspicuous moraines. It seems most probable that the terminal moraines of the great inland ice would consist of low banks of bowlder clay and aqueous materials—the latter, perhaps, strongly predominating, and containing here and there larger and smaller angular erratics which had traveled on the surface of the ice. However that may be, it is certain that the whole region in question has been considerably modified by subsequent denudation, and to a large extent is now concealed under deposits belonging to later stages of the Pleistocene period. The extreme limits reached by the ice are determined rather by the occasional presence of rock striæ and *roches moutonnees*, of bowlder clay and northern erratics, than by recognizable terminal moraines. The southern limits reached by the old inland ice appear in this way to have been tolerably well ascertained over a considerable portion of Central Europe. Some years ago I published a small sketch map ("Prehistoric Europe," 1881) showing the extent of surface formerly covered by ice. On this map I did not venture to draw the southern margin of the ice sheet in Belgium further south than Antwerp, where northern erratics were known to occur; but the more recent researches of Belgian geologists show that ice probably flowed south for some little distance beyond Brussels (see a paper by M. E. Delvaux, *Ann. de la Soc. geol. de Belg.*, t. xiii., p. 158). Here and there in other parts of the Continent the southern limits reached by the northern drift have also been more accurately determined, but, so far as I know, none of these later observations involves any serious modification of the sketch map referred to.

I have now said enough, however, to show that the notion of a general ice sheet having covered so large a part of Europe, which a few years ago was looked upon as a wild dream, has been amply justified by the labors of those who are so assiduously investigating the peripheral areas of the "great northern drift." And perhaps I may be allowed to express my own belief that

* Opening address by Prof. James Geikie, LL.D., F.R.SS. L. & E., F.G.S., president of section C, British Association, Newcastle, 1889.

* "Untersuchungen uber die Klimate der Gegenwart und der Vorwelt," etc. (*Natuurkundige Verhandelingen v.d. Holland. Maatsch. d. Wetensch. te Haarlem*, 1865).

† These appear to have been first detected by Prof. Berendt and Prof. E. Geinitz.

* "Die Vergletscherung des Salzachgebietes," etc., *Geographische Abhandlungen herausgegeben v. A. Penck*, Band i. Heft 1.

the drifts of Middle and Southern England, which exhibit the same complexity as the "lower diluvium" of the Continent, will eventually be generally acknowledged to have had a similar origin. I have often thought that while politically we are happy in having the sea all round us, geologically we should have gained, perhaps, by its greater distance. At all events, we should have been less ready to invoke its assistance to explain every puzzling appearance presented by our glacial accumulations.

I now pass on to review some of the general results obtained by Continental geologists as to the extent of area occupied by inland ice during the last great extension of glacier ice in Europe. It is well known that this latest ice sheet did not overflow nearly so wide a region as that underneath which the lowest bowlder clay was accumulated. This is shown not only by the geographical distribution of the youngest bowlder clay, but by the direction of rock strim, the trend of erratics, and the position of well marked moraines. Gerard de Geer has given a summary (*Zeitschrift d. deutsch. geolog. Ges.*, Bd. xxxvii., p. 177) of the general results obtained by himself and his fellow workers in Sweden and Norway; and these have been supplemented by the labors of Berendt, Geinitz, Hunchecorne, Keilhack, Klockmann, Schroder, Wahnschaffe, and others in Germany, and by Sederholm in Finland.* From them we learn that the end moraines of the ice circle round the southern coasts of Norway, from whence they sweep southeast by east across the province of Gottland in Sweden, passing through the lower ends of Lakes Wener and Wetter, while similar moraines mark out for us the terminal front of the inland ice in Finland—at least two parallel frontal moraines passing inland from Hango Head on the Gulf of Finland through the southern part of that province to the north of Lake Ladoga. Further northeast than this they have not been traced; but, from some observations by Heimersen, Sederholm thinks it probable that the terminal ice front extended northeast by the north of Lake Onega to the eastern shores of the White Sea. Between Sweden and Finland lies the basin of the Baltic, which at the period in question was filled with ice, forming a great Baltic glacier, which overflowed the Aland Islands, Gottland, and Oland, and which, fanning out as it passed toward the southwest, invaded, on the north side, the Baltic provinces of Germany, while on the north it crossed the southern part of Scania in Sweden and the Danish islands to enter upon Jutland.

The upper bowlder clay of these regions is now recognized as the ground moraines of this latest ice sheet. In many places it is separated from the older bowlder clay by interglacial deposits, some of which are marine, while others are of fresh water and terrestrial origin. During interglacial times the sea that overflowed a considerable portion of North Germany was evidently continuous with the North Sea, as is shown not only by the geographical distribution of the interglacial marine deposits, but by their North Sea fauna. German geologists generally group all the interglacial deposits together, as if they belonged to one and the same interglacial epoch. This, perhaps, we must look upon as only a provisional arrangement. Certain it is that the fresh water and terrestrial beds, which frequently occur on the same or a lower level, and at no great distance from the marine deposits, cannot in all cases be contemporaneous with the latter. Possibly, however, such discordances may be accounted for by oscillations in the level of the interglacial sea—land and water having alternately prevailed over the same area. Two bowlder clays, as we have seen, have been recognized over a wide region in North Germany. In some places, however, three or more such bowlder clays have been observed overlying one another throughout considerable areas, and these clays are described as being distinctly separate and distinguishable, the one from the other.† Whether they with their intercalated aqueous deposits indicate great oscillations of one and the same ice sheet—now advancing, now retreating—or whether the stony clays may not be in the ground moraines of so many different ice sheets, separated the one from the other by true interglacial conditions, future investigations must be left to decide.

The general conclusions arrived at by those who are at present investigating the glacial accumulations of Northern Europe may be summarized as follows:

1. Before the invasion of Northern Germany by the inland ice, the low grounds bordering on the Baltic were overflowed by a sea which contained a boreal and arctic fauna. These marine conditions are indicated by the presence under the lower bowlder clay of more or less well bedded fossiliferous deposits. On the same horizon occur also beds of sand, containing fresh water shells, and now and again mammalian remains, some of which imply cold and others temperate climatic conditions. Obviously all of these deposits may pertain to one and the same period, or more properly to different stages of the same period—some dating back to the time when the climate was still temperate, while others clearly indicate the prevalence of cold conditions, and are therefore probably somewhat younger.

2. The next geological horizon in ascending order is that which is marked by the "lower diluvium"—the glacial and fluvio-glacial detritus of the great ice sheet which flowed south to the foot of the Harz Mountains. The bowlder clay on this horizon now and again contains marine, fresh water, and terrestrial organic remains, derived undoubtedly from the so-called preglacial beds already referred to. These latter, it would appear, were plowed up and largely incorporated with the old ground moraine.

3. The interglacial beds which next succeed contain remains of a well marked temperate fauna and flora, which point to something more than a mere partial or local retreat of the inland ice. The geographical distribution of the beds and the presence in these of such forms as *Elephas antiquus*, *Cervus elephas*, *C. megaceros*, and a flora comparable to that now existing in Northern Germany, justify geologists in concluding that the intergacial epoch was one of long duration, and characterized in Germany by climatic conditions apparently not less temperate than those that now obtain. One of the phases of that interglacial epoch, as we have seen, was the overflowing of the Baltic provinces by the waters of the North Sea.

4. To this well marked interglacial epoch succeeded another epoch of arctic conditions, when the Scandinavian inland ice once more invaded Germany, plowing through the interglacial deposits, and working these up in its ground moraine. So far as I can learn, the prevalent belief among geologists in North Germany is that there was only one interglacial epoch; but as already stated, doubt has been expressed whether all the facts can be thus accounted for. There must always be great difficulty in the correlation of widely separated interglacial deposits, and the time does not seem to me to have come when we can definitely assert that all those interglacial beds belong to one and the same geological horizon.

(To be continued.)

* For papers by Berendt and his associates see especially the *Jahrbuch d. k. preuss. geol. Landesanstalt* and the *Zeitschr. d. deutsch geol. Ges.* for the past few years. Geinitz, *Forsch. z. d. Landes. u. Volkskunde*, i. 5; *Leopoldina*, xxii. p. 37; *I Beitrag z. Geologie Mecklenburgs*, 1880, pp. 46, 56. Sederholm, *Fennia*, i., No. 7.

† H. Schroder, *Jahrb. d. k. preuss. geol. Landesanstalt fur* 1887, p. 360.

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